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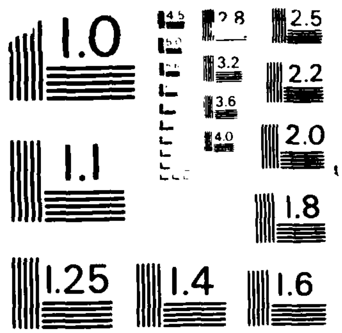

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963

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AN ANALYSIS OF THE SPACE SECTOR'S SURGE

CAPACITY: AN INPUT-OUTPUT APPROACH

THESIS

William K. Murphy
Captain, USAF

AFIT/GSO/ENS/86D-18

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List of Figures

List of Tables

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Abstract

This ~~study~~ examines the Space sector's surge capacity in the context of the classical input-output paradigm. It takes as its basis for evaluating the surge potential the concept of available industrial capacity, using the methodology proposed by Michael D. Miller in his report, "Measuring Industrial Adequacy for a Surge in Military Demand."

The investigation begins with a brief history of this country's mobilization and surge policies, and analyzes the need for industrial planning in the Space sector. The study then focuses on the functions of space operations, and its necessary products. Next, it develops a working definition of the Space sector.

A discussion of input-output analysis, its theory, applications, and limitations is included to set the stage for determining the Space sector's interindustry dependencies--at all levels of the economy.

The study concludes by calculating the amount of production required for each industry to support a surge in space products, and also determining the vulnerability each industry faces in supporting that surge.

To my family, Ken, Rob, Cathy, and even Dorothy, thanks for all your phone calls. Its nice when brothers and sisters remind you that Ohio doesn't have to be forever. Mom, thanks for all your concern--it went to good use. And Dad, thanks for teaching me that computers don't have to bite back.

Finally, I want to express my deepest gratitude and love to Bernadette, my fiancee. Your complete understanding was only exceeded by the love and confidence you had in me. Thankyou sweetheart, you made it all worthwhile.

William K. Murphy
26 Feb 1987

AN ANALYSIS OF THE SPACE SECTOR'S SURGE
CAPACITY: AN INPUT-OUTPUT APPROACH

I. Introduction

This chapter establishes the need and framework for this thesis. It briefly discusses the history of this country's mobilizaion and surge policies, and analyzes one of its associated weaknesses--inadequate industrial planning. It shows why industrial planning--in this case, in the Space sector--is needed to assess the interelationships between the tiers of production and thus, provide for a stronger defense industrial base. The basic objective this thesis attempts to accomplish is stated, along with subsidiary objectives addressed in the research. Next, the approach and methodology of the research are described, including the limitations which must be assessed when reviewing the findings of this study. Finally, an outline of the remainder of the thesis is presented.

Background

Inherent in the rational of this manuscript is the clear understanding that the Department of Defense (DoD) must evaluate the defense industry's ability to mobilize and surge in response to present and future defense needs. Mobilization is defined as the process of preparing the armed forces for "war or other national emergencies by assembling and organizing the natural resources needed"

(51:36). A declaration of war or national emergency must exist to impliment mobilization. On the other hand, surge capacity deals with the industry's ability to accelerate production in support of any event short of war or a national emergency. However, even though a rapid response in a surge situation is usually critical, executive powers are not available to facilitate implementation (51:36).

Today's mobilization and surge policies originated as a result of industry's slow response during WWI. In 1920, Congress passed the National Defense Act of 1920 to establish an industrial planning organization under the Secretary of War. This organization developed contingency plans to facilitate the procurement of military equipment in the event of war (37:18).

In 1947, as a result of the Cold War, sponsors of the National Security Act of 1947 created the National Security Reserve Board (NSRB). NSRB was the first permanent civilian agency responsible for peacetime mobilization/surge planning. NSRB was responsible to coordinate manpower, maintain strategic and critical materials, and evaluate the relocation of strategic industries (52:28).

With the outbreak of the Korean War in 1950, President Trueman created the Office of Defense Mobilization to manage the mobilization effort. In addition, Congress passed The Defense Production Act of 1950 to give the President the authority to "strengthen the mobilization base, produce

military goods, control and stabilize the economy and, in general, mobilize the country's resources in support of the war effort" (52:28). In 1953, President Eisenhower realized the importance of a consolidated mobilization/surge agency and combined the NSRB and office of Defense Mobilization.

Today, the Federal Emergency Management Agency (FEMA), in conjunction with the Department of Commerce and the Department of Defense (DoD), is responsible to evaluate industry's capability to mobilize and surge in reponse to national and world events. Nevertheless, inadequate industrial planning is still one of the significant problems facing the defense industries today. For example, in 1974 Congress requested that the DoD increase its tank production as a result of the 1973 Mideast War; however, the defense industry was unable to respond. Chrysler, the prime contractor, had the tank-building capacity, but a lack of casting at the subcontractor level stopped production (31:10). In 1980, Mr. Grey, chairman of the board for United Technologies, testified on the condition of the defense industrial base before the Armed Services Committee, and stated: "The supplier network that forms the base of our country's defense industry is shrinking at an alarming rate" (51:35). These closures have drastically effected production and procurement lead times in all areas of the defense industry. Lawrence Korb, former Assistant Secretary of Defense, recognizes the problem and advocates the need for "specific industrial preparedness planning"

that is actually part of DoDs Planning, Programming, and Budgetary System (PPBS) (39:32).

Nowhere is the need for adequate industrial planning more important than in today's Space sector. Low production quanities, extreme reliability testing, and unique requirements constantly constrain the sector to a relatively small number of prime contractors and highly specialized subcontractors (61:ES5). These factors all create a production environment extremely dependent on advance planning. Camouflaged by steady growth trends (61:ES), the Space Sector's overall strength is misdiagnosed by evaluating individual firms financial sheets. Instead, sectorial analysis that focuses on the interrelationships between the tiers of production (31:281), and studies the inputs and outputs of all industries involved in the production (38:35) of space commodities is needed to provide a safer warning of production problems. In addition, the Space sector may soon face a drastic increase in production demand. Extensive research and development is under way to bring a U.S. Space Station and a Stategic Defense Initiative (SDI) to fruition. Material and production requirements, the nature of which the Space sector has never seen, may soon develop. One contractor has proposed a space based defense system consisting of 50,000 satellites. Even if the small amount of prime contractors that manufacture satellites could produce these number of satellites, does

the U.S. even have the launch capability to put them into orbit? Without any SDI lift requirements, the U.S's yearly payload requirements are increasing from roughly 700 metric tons to over 1000 metric tons by the early 1990's. If SDI requirements are added, estimates for the combined annual mass delivery could soar to over 3,000 metric tons (44:3). Finally, if all this was not bad enough, SDI, with its possible large increase of on-orbit satellites, would put a large strain on the available ground base satellite control systems (9:177). Is the Space sector prepared to build and support systems of this size? Or, like the tank industry of 1974, are production and material bottlenecks likely to cause major program delays?

Problem Statement

It appears that little has been done to quantitatively analyze the Space sector in terms of the interdependence of its various industrial components and the requirements placed on those components to satisfy its final demand.

Specific Objective

The purpose of this investigation is to identify the product flows between the Space sector's major production and lower-tier industries, and to study the effects of a sudden increase in DoD demand (surge) on these product flows.

Subsidary Objectives

1. Desribe current day space operations.

    a. Identify and desribe the componets/segments common to all space operations today, and the various missions that space operations support.

    b. Identify the necessary products the space sector produces to support today's space operations.

2. Define the Space sector.

    a. Identify the major industries, by SIC code, that produce space products.

    b. Identify all major buyer/supplier relationships for the market.

    c. Identify the structural characteristics of the idustries identified in (a) above.

        1) Determine number of actual potential competitors.

        2) Determine concentration ratios of industries.

        3) Determine extent of barriers to entry.

3. Determine if input-output analysis is an appropriate method to analyze industrial interrelationships and military surge capability.

4. Identify the dependence of the Space sector on other industries, i.e., identify the significant lowertier industries.

5. Calculate the necessary increase in output for all lower-tier industries to support the surge scenario, and evaluate the economy's potential to support such a production surge.

Methodology

As a means of achieving the research objective, this study utilizes input-output analysis to identify the interdependence of the manufacturing industries that support

the Space sector, and quantitatively evaluate their potential to meet the production requirements brought about by a surge in the demand of space products.

The first part of this study is to provide an understanding of today's space operations and the products that support its missions--this is a two-step process. First, space operations is broken down into the fundamental segments inherent to all space missions. Second, all major space products that are necessary to carry out these mission are identified and desribed by their major subsystems.

The next step in this research effort developes a working definition of the Space sector. All industries that produce space-related products are identified by Standard Industrial Classification (SIC). Major buyer/supplier relationships are identified and evaluated based on percentages of total shipments. Structural characteristics of the industries identified above are determined. Specifically, the size of each industry, the concentration ratios for each industries, the assets, sales, and value added, is determined from Census of Manufacturing data.

The third step in this research project reviews the use of input-output analysis as a method to evaluate production surge capability. A literature review on input-output analysis provides an overview of the theory, including its basic assumptions and limitations. Since input-output analysis has been applied to a wide range of studies, from single firm production processes to entire economies, it was

impossible to review them all. Instead, this literature review focused on how input-output ananlysis has been used to evaluate changes in defense expenditures.

The next portion of the project identifies the dependence of the Space sector on other industries. This information is obtained through Volume I of the Detailed Input-Output Structure of the U.S. Economy. This puplication is produced by the Bureau of Economic Analysis (BEA), and provides the information necessary to identify all those industries that aid, both directly and indirectly, in the final production of space products.

The final part of this project utilizes a modified version of input-output analysis of the form:

$$(I - A)^{-1} C = X \qquad (1)$$

Where:

X = column vector of total output

C = column vector of final demand

A = matrix of technology coefficients

$(I-A)^{-1}$ = inverse matrix

To calculate the increase in output required by all lower-tier industries necessary to support a surge in demand of space products. The surge scenario used for this study is defined as the doubling total military demand for space

products. This is based on a surge scenario that Space Division used to evaluate its Prime and Subcontractors. The scenario was defined as "the doubling of all military products DoD wide within six months after contract turn-on" (61:2-14). Percentage increases of both the Space sector and its lower-tier industries are determined through the use of the above relationship (1), and total requirement values obtained in Volume II of <u>The Detailed Input-Output Structure of the U.S. Economy</u>. These figures are each compared to their industry's capacity utilization values to determine a measure of production response capability.

<u>Scope</u>

This research will deal only with determining the composition of the Space sector, and evaluating the interactions between its major production industries and the lower-tier industries that support the production of space commodities. Specific capabilities of individual firms are not assessed. In addition, this research is limited to a surge scenario, and not a full scale mobilization. A surge scenario relates to a "peacetime increase in military production" (37:11), were firms are free to decide their own mix of defense and commerical products. This is in contrast to mobilization where the government, through enactment of the Defense Product Act of 1950, could assume over the economy's production facilities and designate what each firm will produce.

Next, this research is limited by the assumptions inherent in input-output analysis: no two commodities are produced jointly, all production is efficient, and the ratio of inputs used in production are employed in fixed proportion--all production functions are linear (thus, there is no substituting one input for another in the production of a final good).

In addition, any complete analysis of a sector's ability to surge production depends on plant capacity, labor availability and critical material availability. This research just focuses on plant capacity.

Finally, this research is limited by the data available. Due to the amount of work/time involved in collecting census data, the most current and complete data is limited to the 1977 Bureau of Economic Analysis Input-Output Tables, published in 1984. In addition, the most current capacity utilization rates available are the Census Bureau's 1984 edition.

II. Space Operations

Chapter one emphasized the need to evaluate the Space sector and determine if the lower levels of the defense industrial base can support a surge in production. However, before proceeding with such a study, it is necessary to understand todays space operations, specifically the functions it performs and the products it utilizes. This chapter examines space operations first, in terms of the four interrelated segments that comprise all space operations; and second, in terms of the current space products used to carry out todays operations in space.

Introduction

Since the ancient times man has looked to the heavens to help him know where he was going and even what time it was. However, in the last few decades man has done more than just look to the stars, man has ventured out into space and utilized it for more benefits than people a century ago would have dreamed. However, it was not until the Soviet's launched Sputnik in 1957, that the U.S. really understood the importance of space and the necessity of space operations.

The military was the first to grasp the importance of space. Seen as more than just a scientific playground, the military immediately recognized space as a "force enhancer". Today, the military uses space for a plethora of missions from reconnaissance (photographic, electronic, and oceanic),

to early warning, to communications, to navigation, to meteorological. However, the military is not the only user of space. Space Commerce has grown from "scientific fantasy to economic reality" in just the last ten years (31:3). Utilizing many of the same missions, though for different purposes, commercial interests are reaching for the stars for a chance at astronautical profits.

At the heart of converting these dreams into reality is space operations. Space operations is the ability to oversee/interact with space products to function efficiently in space. The purpose of this chapter is to examine space operations, both in terms of its functions and its necessary products, to provide a foundation from which a clearer understanding of the Space sector can be obtained.

Space Operations

Today's space operations can best be thought of as an interaction of various technical services and hardware. It is a technical process that entails both planning and controlling missions in space. There are a variety of space missions ranging from recording weather patterns here on earth to probing deep space in search of clues to unravel the riddles of the universe. Yet regardless of the variance of these missions, all space operations consist of four interrelated segments: launch, control, space, and user (10:112). The purpose of this section is to explain each segment of space operations to provide an understanding of

what products are necessary for the Space sector to produce.

Launch Segment. The first in a series of four interrelated segments, the launch segment deals with inserting a spacecraft into a specified orbit. (More will be said about exactly what a spacecraft is later in this study). The launch segment is really a sequence of events that depends on the spacecraft's specified orbit. An orbit is just a path through space, a trail to get a spacecraft to some destination. Some destinations are only a hundred miles above the earth, while others are millions of miles away. Most spacecraft today operate either in a low earth orbit or a geosynchronous orbit. A low earth orbit is a general term for a variety of orbits with altitudes of about 200 km and are used mainly for surveillance and meteorlogical missions. On the other hand, geosynchronous orbits have an altitude of 35,768 km and are used mainly for communications missions. Unlike spacecrafts in low earth orbits, geosynchronous spacecrafts move around the earth with a period of revolution exactly equal to the earth's period of revolution. Thus, to an observer on the earth, the spacecraft appears to be directly overhead at all times.

The uniqueness of geosynchronous orbits, and its application to communications, was pointed out back in 1945 by Arthur C. Clark. He showed that just three geosynchronous satellites, powered by solar energy, could provide continuous worldwide communications (2:9). It was

just twenty-four years later that Clark's dream became a reality. In 1969, the Intelsat III series satellites, built by TRW, were launched and put into orbit over the Atlantic, Pacific, and Indian oceans to achieve full global communication coverage (2:15).

Fthenakis, in his text, Manual of Satellite Communications, breaks out the launch sequence for a geosynchronous communication satellite, like the Intelsat III series, into five steps (29:37-39):

> 1. The main launch vehicle is ignited, and after lift-off, during the main boost phase, the craft is powered through the earth's atmosphere. In order to avoid the effect of severe aerodynamic forces during the powered flight, only limited and absolutely necessary maneuvering is performed.
>
> 2. As soon as the upper stages of the launch vehicle exit the atmosphere [and enter into low earth orbit], the fairing is jetisoned. The fairing, which covers the spacecraft on the top of the launch vehicle to protect it from the aerodynamic forces during powered flight, is no longer needed.
>
> 3. The final stage of the launch vehicle ignites [in low earth orbit]; after burnout, the spacecraft is injected into the transfer orbit near the perigee. This orbit is a highly elliptical one with an apogee at [geo]synchronous altitude.
>
> 4. After the payload has been tracked from the ground and a precise determination has been made of the orbital parameters -- a task that takes several orbital periods -- the apogee kick motor (AKM) is ignited at the apogee in order to remove the inclination of the orbital plane (orbital plane correction) and, at the same time, to circularize the orbit. Before igniting, the thrust vector is oriented appropriately by commanding, from the ground, the attitude orientation system of the spacecraft.
>
> 5. The spacecraft is attitude-stabilized and is set to

operate on its own electrical power. Over a period of several days, the spacecraft is tracked from the ground and -- through its own secondary propulsion system activated by ground commands -- is positioned on station in order to commence operations.

Note that the launch sequence described above is typical for a Titan III C launch vehicle. The use of a different launch vehicle, such as the Space Shuttle, would not be identical, and would have a different sequence of events. Nevertheless, this example provides one with a feeling for the procedures and the equipment necessary to carry out the launch segment of space operations.

Control Segment. Bowman's next segment of space operations, the control segment, is merely an extension of the launch segment. The control segment monitors spacecraft health and directs spacecraft operations from the ground at satellite control facilities. Spacecraft health is monitored and maintained by interacting with the spacecraft's major subsystems: Attitude Control, Secondary Propulsion, Electric Power, Thermal Control, Telemetry and Command (2:3; 29:45). (More will be said about these subsystems later in this study under spacecraft description.) Specific responsibilities include acquiring spacecraft position data; orbit determination; informing clients of satellite overflight time; analyzing and correlating orbit calculations results; analyzing and following up tracking network performance; collecting orbital parameters from all other space agencies; running an orbit data base; and operating tracking software.

Space Segment. The space segment includes both on-orbit operations and spacecraft servicing. Specific on-orbit operations depend on the spacecraft's mission. Today's spacecraft are used for more than just communications; they are also used for various forms of remote sensing (such as, earth observation, surveillance, and meteorological reporting), navigational aids, exploration, and even manufacturing.

Communication. Today's communications satellites have come a long way since 1965, when Early Bird was the first communications satellite (33:565). Today, the US alone has over forty-five communications satellites in orbit above the earth. These spacecraft aid in all forms of communication from personal telephone calls to business teleconferencing to complete area networks to direct broadcast services (33:566). Basically, these spacecraft are a configuration of antennas and transponders that act as active repeaters in the sky bouncing a signal from one point on earth to another. The capability of these spacecraft is almost mind boggling. Intelsat VI, built by Hughes in 1986, can carry 40,000 two-way telephone circuits plus two TV channels. This is a far cry from the 240 two-way telephone circuits or one transatlantic TV channel that Early Bird carried in 1965 (2:15-16).

Remote Sensing. Remote sensing, as mentioned above, comprises various forms of measuring the earth's

surface and its surounding environment. Earth observation, surveillance, and meteorological are the more common known forms. Measurments performed by remote sensing can either be passive, such as photographing the earth; or active, which involves bouncing light waves off the ground and measuring the spectral frequencies not absorbed by the objects on the earth (31:75).

Earth observation (also known as earth resource) and surveillance spacecraft are used for a variety of purposes ranging from agricultural crop classification to ballistic missile launch detection. Observation/surveillence spacecraft are basically a collection of remote sensors operating throughout the elctromagnetic spectrum. Since each object on earth has its own spectral signature, recordings made by a spacecraft can be compared to data banks on earth of known spectral signatures to evaluate what the spacecraft is viewing. For example, an observation spacecraft like Lansat-D, developed by General Electric, carries two remote sensing instruments: a thermatic mapper and a multispectral scanner (MSS) (65:998). The MSS is a four-channel radiometer. Not as sophisticated as the thermatic mapper, it provides images in only four bands; green, red, and two infrared bands. On the other hand, the thermatic mapper is a seven channel radiometer and provides images in seven spectral bands (2:8). These sensors allow Landsat to collect data about the earth which, together with environmental information from earth-based platforms, aids

research in geography, cartology, forestry, geology, and hydrology (65:997).

Meteorological. Meteorological spacecraft, which assist in weather forcasting, are another form of remote sensing. Instead of a MSS or a thermatic mapper, a meteorological spacecraft's primary payload is usually a very high resolution radiometer (VHRR). The VHRR takes both visual and infrared images of the earth and cloud movements. In addition, most spacecraft are used in a communications mode, as a relay, to connect isolated measuring instruments around the world with central weather stations (2:1).

User Segment. The user segment, the final segment of space operations, interacts with the space segment to give utility to operations. An example is Britain's military interaction with meteorological spacecraft during the Falkland Conflict (Operation Corporate) in 1982. Since the South Atlantic is known for its adverse winter conditions, the British, in an effort to ensure a successful operation, sought out meteorological and oceanografic support. Through a "special agreement" with the U.S., two meteological spacecraft, NOAA-6 and NOAA-7, performed special passes over South America and the South Atlantic to gather data. This information, which was relayed down to ships in the task force and meteorological units supporting the Royal Airforce, proved valuable in taking maximum advantage of oceanographic fog and cloud conditions.

Products of the Space Sector

Throughout the preceeding discription of space operations, three general products were specifically mentioned time and time again. These three products have traditionally categorized the poduction activities of the Space sector (53:14):

-the development and manufacturing of spacecraft which differ according to their mission/function.

-the development and manufacturing of launch vehicles to deliver spacecraft into orbit.

-the construction of ground stations and development of equipment necessary to command/communicate with the systems described above.

The purpose of this section is to describe each of these products and provide some examples to help understand what the Space sector produces.

Spacecraft. The product in this section pertains to designed, engineered, and constructed systems that operate in space. Specifically, it refers to artificial satellites, manned space vehicles, space stations, and space probes. (Since a majority of spacecraft over the last two decades have been artificial satellites this report will center around them in its discussion on spacecraft.) These spacecraft perform a variety of missions from weather forecasting to interplanetary exploration. Yet regardless of the diversity of these missions, all spacecraft can be devided into two basic parts: the mission payload, and the spacecraft bus (2:1). The mission payload, as discussed above in the space segment of space operations, consists of

complex technical equipment necessary to carry out various missions in space--communications, meteorology, earth resources/surveillence. A payload is not designed to survive in space on its own, rather the payload depends on the spacecraft bus to support it. The spacecraft bus, for an unmanned spacecraft, is composed of five general subsystems: Attitude Control, Secondary Propulsion, Electric Power, Thermal Control, and Telemetry and Command.

Attitude Control. External forces, such as solar radiation pressure, magnetic fields, and gravity gradients, all generate unnecessary torques that disturb a spacecraft. Attitude control monitors these disturbances and maintains the spacecraft's attitude and orientation in space. The configuration of the attitude control system depends heavily on the type of stabilization the spacecraft employs. The two primary methods of stabilization used today are spin stabilization and three axis stabilization (2:33-34; 29:45). Both methods rely on the interaction of sensors, torques, and angular momentum storage devices with the secondary propulsion system. The control subsystem is usually monitored and directed from facilities on the ground through the telemetry and command subsystem (2:3).

Secondary Propulsion. The secondary propulsion system is separate and unique from the main propulsion system used during the launch segment. The secondary system has three major functions (29:66). First, it insures the

spacecraft's final injection into the desired orbit. (For some geosynchronous spacecraft, this function is performed by a separate solid propellant motor that is attached to the spacecraft (2:23, 29:66). (More will be said later about kick motors in a discussion on various launch vehicles.) Second, the secondary propulsion system is needed for station keeping and positioning on station (29:66). Station keeping refers to maintaining the spacecraft's final orbit and correcting for pertubations due to irregular gravitational effects of the earth and third-body effects of the sun and moon (62:118). Positioning on station is the spacecraft's ability to rotate and change orientation to aid in the performance of the spacecraft's mission. Third, a propulsion system is required to aid in the attitude control of a spacecraft. For spin stabilized spacecraft, a secondary propulsion system is required for maintaining the spin rate. A typical spin rate for this type of spacecraft is 100 revolutions per minute. For three-axis stabilized spacecraft, propulsion is needed to help unload the momentum package after it saturates (29:66). To accomplish these functions, most spacecraft rely on auxiliary rockets. There are three types of auxiliary rockets: cold gas jets, warm or heated gas jets, and chemical combustion rockets (61:163). As Sutton points out, "all are basically pressurized feed systems with multiple thrust chambers equipped with fast-acting, positive-closing, precision valves" (61:164).

Electric Power. Electric power is the life blood of a spacecraft and is provided to the spacecraft through an electric power subsystem. The primary source of elctric power is solar energy: the conversion of light photons into electricity through solar cells (2:2-3). During periods when the spacecraft is without sunlight, rechargable batteries are used. (A geosynchronous spacecraft can experience up to 88 eclipses during a one year period with a maximum duration of 70 minutes a day (63:66).) When not in use, these batteries are constantly charged by the spacecraft's solar arrays. In addition to the solar arrays and rechargable batteries, the power system is composed of voltage regulators, current limiters, switching relays, and various other power/control electronic devices to control the spacecraft's voltage (29:65).

Thermal Control. The unique environment that spacecraft operate in expose them to wide fluctuations of temperature. For example, the solar arrays of a three axis stabilized spacecraft can vary from as much as 60 degrees Centigrade (C) in direct sunlight to -160 degrees C during an eclipse. Yet, many spacecraft components need to operate in a much more restricted temperature range. Batteries, critical to a spacecraft during an eclipse, must be kept between 0 and 25 degrees C to operate properly (2:226). At the other extreme, a Visible and Infrared Spin Scan Radiometer (VISSR), used on meteorological spacecraft, must

operate down at a cool -178 degrees C (2:48). Thus, a thermal control subsystem is vital to provide each temperature sensitive component an environment to operate in.

To achieve efficient/effective thermal control, most spacecraft rely on the use of both passive and active techniques (2:292; 12:461). Passive control systems have no moving parts or fluids, require no energy input from the spacecraft, and are simpler, less expensive and more reliable to operate than active systems (12:462). Passive thermal control techniques include the following: thermal coats--such as special paints to control the spacecraft's suface emissivity and solar absorption, thermal insulators--such as Mylar or Kapton to decrease the rate of heat exchange between two boundaries (2:295, 12:462), heat sinks to pull excessive heat away from electrical components, and phase change materials to help control "wide orbital heat flux changes during short periods of time" (2:297).

Active control systems are used to supplement the passive controls. They rely mainly on electric heaters, flaps and louvers, and heat pipes. Electric heaters, plugged directly into the spacecraft's electric power source, are used to keep special components warm (much in the same way an electric heater is used to keep a car engine warm in the winter). Flaps and louvers, also powered by the spacecraft's power source, are used to change the emissivity and solar absorptivity of the spacecraft's surfaces.

Finally, heat pipes are used to transfer excessive heat from a heat source to a heat sink where passive systems are not adequate (12:462).

Telemetry, Command, and Control. This subsytem maintains a two-way command and data link between the spacecraft and the ground stations. Telemetry is the one-way flow of information from the spacecraft to the ground that allows the user to monitor the spacecraft's subsytems and payload (2:4; 12:463). Onboard sensors and tranducers monitor both the spacecraft's environment, such as the surrounding temperature or radiation level, and the spacecraft's health, such as its fuel level or battery charge. This information is sent down to ground control via transmitters and antennas.

The command and contol portion completes this two way communication system. Basically, it is just an extension of ground control--it receives and carries out their control commands. It is constructed with command antennas, receivers, decoders, and driver amplifiers. Decisions, based on telemetry data discussed above, are transmitted from the ground and received by the spacecraft's command antennas. The signal is then demodulated by receivers and, if necessary, decoded. The electric signals are then amplified and used to drive the spacecraft's necessary subsystems.

The five subsystems listed above are highly integrated. In adition to being ultimately under the command of the control facility, each subsystem requires inputs from the others. Figure I shows this interaction (29:60):

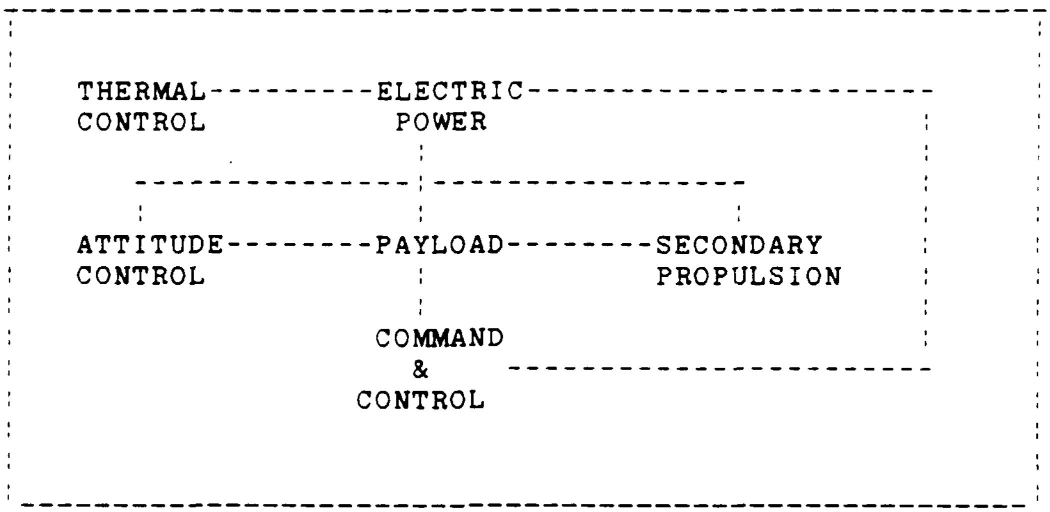

Figure 1. Spacecraft Subsystem Interaction

Today, the U.S. has many operational spacecraft. The majority, however, are operational earth satellite systems. Table I lists the forty-four current systems and identifies the user and manufacturer. (Note, the satellites are broken out by function. In many cases a satellite system can, and does, perform more than one function; nevertheless, each system has only been associated with its primary function.)

Table I

CURRENT SATELITE SYSTEMS

Communications	
TDRSS A,B,C	** ACTS
Westar 1, 2,3/4, 5, 7	Marisat 1, 2, 3
Comstar 1, 2, 3, 4	Spacenet
G STAR	SBS 1, 2, 3, 4, 5
Telstar-3 1, 2, 3	Galaxy 1, 2, 3
Amersat	Satcom
** STC/DBS	** DBSC
** Fordsat	DSCS-2
DSCS-3	FleetSatCom 1-8
Satellite Data System	Leasa
** Milstar	
Observation/Remote Sensing	
Landsat 4	Dynamics Explorers 1/2
** GRO	** International Solar Polar
Solar Mesophere Explorer	SCATHA
AMPTE-CCE, IRM, UKS	ERBS
P-78-1	CRRES
** COBE	AEROS
** URAS	MIDAS
KH-11 Stategic Recon	High Resolution Film Recon
Ocean Surveillance 1	Defense Support Program
Ferret	Clipper Bow
Weather Forcasting	GEOS
NOAA 7, 9, G, H, I, J	TIROS
DMSP	
Exploration	
Voyager 1, 2	Galileo
**Hubble Space Telescope	Mariner
Viking	
Navigation	
Navstar/GPS	Nova
SOOS-Stacked Oscars on Scout	Navsat

** System has not yet been deployed.

Source: 57:172

Space Launch Vehicles. Space launch vehicles refer to systems capable of putting spacecraft weighing several hundred kilograms into space. There are many different types of launch vehicles, and many different ways to classify them. Nevertheless, all launch systems consist of a basic space vehicle airframe, propulsion/fuel systems, and miscellaneous hardware (53:14). For the purposes of this study, there are three types of launch vehicles: Space boosters (which include upper stages), guided missles, and research rockets.

Space boosters are the most commonly known launch systems. Proudly displayed on television before millions of people during the Gemini, Apollo, and Space Shuttle missions, these boosters are used to transport spacecraft out of the earth's atmosphere and into space. At present, in lieu of the Space Shuttle Challenger disater on 28 January 1986, and recent failures of both the Delta and Titan boosters, the U.S. has a family of five space launchers. Nevertheless, all five launches are considered viable systems. Table II lists all the launchers, and the weight each launcher an carry to reach both regular operating orbit and escape velocity.

All of the launch vehicles listed in Table II below, except the Space Shuttle, are multi-stage expendable systems. The Scout is the smallest of the launch vehicles and is composed of four solid propellant stages: Algol IIIA first stage, Castor IIA second stage, Antares IIIA third

stage, and Altair IIIA fourth stage (60:6-2). Each stage of the Scout, like the stages of all the launch vehicles, are essentially complete vehicles in themselves. They carry their own propellant (fuel for a liquid rocket), rocket engine(s), and control system (62:13). Thus, once a stage's propellant is used up, the whole stage can be jettisoned to reduce the overall mass of the launch vehicle. This concept of multiple staging allows a launch vehicle to achieve higher velocities and carry greater weights into orbit. The Scout's four stage system can carry approximately 400 lbs into a 300 mile orbit or 75 lbs into an escape trajectory to break away from the earth's gravitational field (Sutton:14).

Table II

U.S Launch Vehicles

Launch Vehicle	Weight To Orbit (lb)	Weight To Escape (lb) Velocity
Space Shuttle	65,000 (200 miles)	N/A
Atlas G/Centaur	5,200 (geosynchronous)	3,500
Titan	8,000 to 33,000 (100 miles)	2,650
Delta	5,600 (100 miles)	1,060
Scout	400	75

Source: 62; 57; 31; 62

The Delta rocket is a modified three stage solid/liquid launch vehicle. Unlike the Scout, the first stage runs off of liquid oxygen, rot solid fuel. To augment lift capability, Castor I solid propellant motors are bolted onto the first stage. Overall, the Delta is cabable of putting 5,600 lbs into a 100 mile orbit, or up to 1060 lbs into an escape orbit (62:14; 60:6-3).

The Atlas rocket, by itself, is a one-stage liquid fuel launch vehicle. With the aid of a centaur upper stage the Atlas is capable of putting 5,200 lbs into a geosyngronous orbit, or up to 3,500 lbs into escape orbit. (Information on upper stages like the centaur is presented below.)

The Titan is the largest of the expendable launch vehicles. Supplemented by two solid rocket motors, the three-stage liguid rocket can lift as much as 33,000 lbs into a 100 mile orbit, or up to 2,650 lbs into escape orbit without the use of upper stages.

The Space Shuttle, unlike the launch vehicles discussed so far, is a reusable system that is composed of three parts: an orbiter, two solid rockets, and an external tank. The orbiter is a winged shape space bus that can carry a payload and crew into orbit, and glides back to earth. The Space Shuttle utilizes both a liquid and solid propulsion system. On lift-off, two solid rocket boosters, in conjunction with the main orbiter's three liquid fuel burning engines, produce enough thrust to boost the shuttle to about 5500 km/hr. After approximately two minutes, the

solid rocket boosters are separated and parachuted back to earth where they are retrieved and refurbished for further use. This unique system allows the Space Shuttle to carry 65,000 lbs of payload into a 200 mile orbit.

In addition to the launch vehicles discussed above, the U.S. uses upper stages to place payloads into final orbit. Upper stages are either solid or liquid propulsion systems attached to both the spacecraft (usally a satellite) and the launch vehicle. In addition, they carry their own electrical, command and control, and guidance systems. The U.S. currently uses six different upper stages, in different configurations with the launch vehicles, to transfer payloads from low earth orbit into medium or geosynchronous orbits. Table III lists the names of current upper stages used by the U.S., the type of fuel they use, and the payload weight the IUS is capable of delivering into geosynchronous orbit.

TABLE III

UPPER STAGES

Upper Stage	Fuel	Pound to Geosynchronous Orbit or Esacape from Earth Orbit
IUS	Solid	With Shuttle 3,300 (planetary) 11,000 (espcape)
PAM	Solid	With Shuttle or Delta 2,500
Centaur	Liquid	With Titan 13,000 With Atlas 3,500
Transtage		
Delta Second Stage		
Stage Vehicle Sys		

Source: 31:43; 57;147; 60

In addition to the production of launch vehicles and upper stages identified above, the development and manufacturing of research rockets and missiles must also be categorized under this general product heading of Launch Systems. Research rockets, designed as test vehicles, are used for various space-related experiments. They place special payloads, such as optical sensors and new materials, into orbit for high altitude research. In addition, they provide a testing bed for new re-enty systems. U.S missiles, on the other hand, have little to do with scientific research. They are mainly offensive and defensive weapon systems that operate both in the earth's atmosphere and in space. Nevertheless, these missiles, especially surface-to-surface missiles, such as Minuteman,

Peacekeeper, and Titan, perform the same function as launch vehicles: transporting a payload through space and into orbit. In addition, these missiles have many of the same propulsion characteristics (type of propellant, thrust profile, acceleration, and duration) and utilize much of the same guidance technology as their big brothers, the launch vehicles.

Ground Equipment. To many people, ground equipment is the least associated with the space sector since it never leaves the ground--nothing could be further from the truth. Ground equipment forms the foundation of today's space operations, and plays an integral part in the launch, control, and the user segments of space operations. All spacecraft today, from the moment they are launched to the moment they splashdown or burn up during reentry, are supported by ground equipment. Ground equipment performs a host of functions, from periodic tracking, to telemetry analysis, to data uploading/downloading (Bleier:177). In addition to controlling spacecraft, ground equipment is also needed to act as an interface between the spacecraft and the user.

Basiclly, there are two types of ground equipment: telemetry, tracking, and control (TT&C) stations; and earth stations. Both stations contain similar telecommunications, tracking, and computer equipment. The major difference between the two stations is the type of information they get from the spacecraft and what they do with it. In fact, it

is possible that a ground station be both a TT&C and earth station; nevertheless, for this study they will be considered separate.

TT&C Stations. TT&C stations are utilized during the launch and control segments of space operations. TT&C stations are interested with knowing the exact location of a spacecraft in time and space. Radar systems, either right at the station or possible a continent away, track spacecraft to provide the necessary information about the spacecraft's azimuth, elevation, range, and velocity. Knowing the spacecraft's location allows stations to retrieve important information from the spacecraft. This information, or telemetry, keeps ground control updated on the health and status of all the spacecraft's systems. Knowing the spacecraft's location also is important so the station can send commands to the spacecraft. Commands sent from the ground can be as simple as turning on a single system, to changing the spacecraft orbit.

A good example is the Air Force Satellite Control Network (AFSCN). The network is a collection of numerous military tracking sites and control centers located throughout the world. These centers and sites support spacecraft launch, early orbit observation, health monitoring, and anomaly resolution (9:177). (In addition, the AFSCN is also responsible for mission tasking and mission data processing--both functions that fall under this

study's heading of ground stations.)

Earth Stations. Earth stations are utilized during the space segment of space operations. They are interested with information from the spacecraft's payload. For example, an earth station associated with a communications satellite would want to know the message or data being relayed by the satellite. Today, there are numerous earth stations throughout the world. Just associated with Intelsat (an international commercial communications satellite consortium) there are over five hundred receiving and transmitting stations (53:28)

All major earth stations, requardless of their affiliation, consit of an antenna dish, antenna feed, uplink transmitters, downlink receivers, tracking systems and various auxiliary systems to supply uninterrupted power and constant temperature control (29:100). Yet, since there are many different types of payloads there is no one specific type of earth station. Earth stations vary in the size of antenna dish, transmitting power, and receiver sensitivity. A good example is the different types of earth stations associated with the Intelsat network. Intelsat has three types of earth stations: Standard A, Standard B, and Standard C. Standard A stations utilize 30 meter or larger diameter parabolic antennas and operate in the 4-6 GHz frequency band. Standard B stations utilize 11 meter antennas which cost less and provide service for areas with less traffic demand. Standard C stations utilize 14-19

meter antennas and are specially designed to operate in the 11-14 GHz frequency band (2:16-17).

Conclusions.

Since the first artificial satellite was launched in 1957, man has constently expanded the uses of space to meet his needs and dreams. Today, space is utilized for everything from communications to surviellance. Yet, no matter how space is used, space operations are needed to oversee/interact with space products. Space operations is comprised of four interrelated segments: launch, control, space, and user. Three products have traditionally been associated with space operations: spacecraft, launch vehicles, and ground stations. Spacecraft, which differ according to their mission, are highly complex pieces of equipment. Most spacecraft are composed of a mission payload and a spacecraft bus (support system). Artificial satellites, manned space vehicles, space stations, and space probes are all types of spacecraft. Of the four, artificial satellites make up the bulk of the U.S. spacecraft today.

Space launch vehicles are systems capable of putting spacecraft weighing hundreds of kilograms into space. Launch vehicles, like spacecraft, are extremely complex pieces of equipment and are usually classified as either expendible or recoverable/reusable. At present, the U.S. has a family of five space launchers: Space Shuttle, Atlas, Titan, Delta, and Scout. In addition, the U.S. uses various

upperstages to assist these launchers in placing payloads into orbit.

Ground equipment, the least associated with space operations, is the third in a triad of space equipment. Ground equipment is composed of varrious TT&C stations and earth stations. Since ground equipment does not have to face the extreme enviroment of space it is not as technologically complex as spacecraft and launchers. Nevertheless, ground systems are composed of some of the most advance electronic equipment today.

It is necessary to understand that each space product and its function is based on current technology. As technology advances, the function each space product performs will evolve. For example, today's satellites, like the first airplanes, are mainly observation and relay platforms used for reconnaissance and communications. However, technological advances may lead to a more combative role for satellites, just as improved anti-aircraft fire stimulated the development of armed aircraft. Today, the genesis of armed satellites is already embedded in the research efforts of SDI. Meanwhile, launch vehicles, such as the Space Shuttle, are developing into orbiting maintenance shops, providing on-orbiting services and assembly. Even the function of today's ground stations may change. Like the first telegraph offices, today's ground stations are the centers for all command and communication.

However, with advances in artificial intelligence, message transmission, processing, and satellite relay capabilities, the space-age telegraph office may be replaced as users bypass the ground stations to access satellites directly -- much the same way personal phones replaced the telegraph office. Requardless of these advances, analysis concerning the economy's ability to produce these products requires a clear understanding of who the producers are. The foundation of this understanding lies in the definition of the Space sector, and is examined in the next chapter.

III. Defining the Space Sector

Chapter one emphasized the need to evaluate the Space sector while chapter two provided a background on the operations the Space sector supports and the equipment it produces. However, before proceeding with this study, it is necessary to define exactly what the Space sector is, and equally important, describe what it is not. This chapter defines the Space sector first, in terms of the industries that comprise it; second, in terms of the major buyer/supplier relationships; and third, in terms of the sector's major structural characteristics.

Introduction

Before a surge potential of space related products can be determined, it is necessary to quantitatively identify what is the Space sector. The Organization for Economic Co-Operation and Development (OECD), in a recent study, emphasized the need for a more accurate definition of the Space sector to aid in the building of a sound statistical base for further analysis (53:57). However, this is no minor task. Even the U.S. Air Force has not clearly defined the space sector. In fact, in the 1986 Space Sector Report, prepared for Air Force Space Division, the Space sector was never defined, just described. Specifically, it was described as being "characterized by very high technology", and "consists [consisting] of relatively small number of

manufacturers capable of being prime contractors for major Space Division programs" (61:ES5). Yet, a description like this is only an observation of the salient identifying features of the Space sector. Unlike a complete definition, this description fails to distinctively outline the features that portray and specify the construction of the Space sector.

The first step in defining the Space sector is to define exactly what a "sector" is. In his text, Industrial Organization, Joeseph Bain describes a sector as a group of firms that produce a variety of products under a general product heading (4:6-7). Bain's general product heading refers to products that have a similar function but are not necessarily direct substitutes for each other. By similar function, Bain is referring to equipment that is engaged in the same kind of action or activity. A direct substitute, on the other hand, refers to products that are easily exchanged for by the buyer during consumption, and also whose production processes possess similar facilities and employ similar skills. Bain further classifies firms within a sector into subgroups called industries. An industry is a collection of firms whose products are direct substitutes for one another, both in consumption and production. Putting it all together, a sector is a collection of similar industries that fall under a general product heading.

This description of a sector forms the foundation for the definition of the Space sector for this study: a segment

or division of the economy, specifically those industries, that produce a collection of space products necessary to carry out current space operations. The purpose of this chapter is to utilize this description to define the Space sector first, in terms of the four major industries that comprise it; second, in terms of its the major buyer/supplier relationships; and third, in terms of sector's major structural characteristics.

Space Sector Industries

The design, development, and production of all space related products is undertaken by a large number of firms. Yet, unless these firms are categorized into specific industries, analysis at an aggregate level would prove difficult. The next step, therefore, in developing a working definition of the Space sector is to identify the specific industries that produce the products described above.

The standard method for classifying industries is set forth in the Standard Industrial Classification Manual 1972. The Standard Industrial Classification (SIC) system was developed by the U.S. Department of Commerce to help classify primary places of business (establishments/firms) by the principle product, or group of products, they produce or distribute (14:10-12). The SIC codes are designed around a series of seven numbers, each successive number representing a more detailed level of classification

(58:59). Under the SIC system, all manufacturing firms are divided into 20 major groups (two-digit SIC). These major groups are further refined into 143 industry groups (three-digit SIC), 450 detailed industry (four-digit SIC), about 1500 product groups (five-digit SIC), and about 11,000 products (seven digit SIC).

Table IV

SIC Code Description

SIC	Description
37	Transportation Equip.
376	Space Craft and Space Craft Equip.
3764	Space Propulsion Units
37646	R&D on propulsion units
3764611	R&D on propulsion units US government military customers

Source: 17

An example of this seven-tiered system is shown above in Table IV. The first two digits, "37" categorize the specific Major Group -- "Transportation Equipment". This refers to any type of manufactured transportation equipment from motorcycle engines to complete space shuttles. The three digit number "376" defines the equipment further down to its Industrial Group -- "Spacecraft and Spacecraft Equipment". This refers to all equipment associated with spacecraft production. Next, the four digit number "3764" represents the detailed "Space Propulsion Industry". This

refers to all equipment used in the production of space propulsion units from the turbopump feed system on a Scout SLV-1A to the complete rocket engine on a Titan missile. The next refinement is the five digit "Product Group". Here, "37646" refers to all of the research and development done in producing propulsion units. The final number, "3764611", is the seven digit code for the specific product. Here, it refers to the research and development done on propulsion units for just U.S. military customers.

Of the five different levels of the SIC code presented above, the most commonly referred to is the four digit detailed industry. According to the Bureau of Census, an industry is defined as "a group of establishments [firms] producing a single product or a <u>closely related group of products</u>" [underline added] (17:VI). It would be convenient if a collection of these four digit SIC industries could be directly taken to compose the Space sector; however, this is not the case. The the methodology used for formulating SIC industries, though very similar, is not exactly the same used in this study. The "single product or closely related group of products", defined above, does not go hand-in-hand with this study's structuring of the Space sector's industries around a collection of firms whose outputs are either space products or direct substitutes for them.

The SIC industry definition is too encompassing. It is possible that a product could be included in a SIC industry

under a 'closely related group of products' and not actually be a direct substitute of a specific product. This problem is best exemplified by the SIC industry that accounts for the development and manufacturing of ground stations. Ground stations, as discussed earlier in this study, are composed mainly of space satellite communications and telemetering equipment. This equipment is found under the Radio and TV Communications Equipment Industry (SIC 3662). However, in addition to this equipment, SIC 3662 also groups together amateur/citizens radio equipment, alarm systems, vehicular and pedestrian traffic equipment, and many more types of equipment that do not classify as space products or substitutes for them.

To work around this problem, SIC product classes (five-digit codes) are utilized as building blocks to construct industries that produce only space products or direct substitutes. Five-digit product classifications are chosen because they are more defined and are based on considerations such as similarity of manufacturing processes and types of materials used (16; 17). These product classes are then grouped together in their respective four-digit industries to form a clearer, more refined picture of the industries that comprise the Space sector. Overall, there were 13 SIC five-digit product groups that represented space products. These product groups were then traced back to four SIC four-digit industries. Table V lists all of the five-digit product classes under their respective four-digit

industries.

In accordance with the space products identified earlier in this study, it is possible to account for what products are produced by what industries above. SIC 3761 accounts for a majority of the space products including the development and manufacturing of spacecraft and launch vehicles without their propulsion systems. SIC 3764 accounts for all firms primarily engaged in the development and manufacturing of the propulsion systems for both spacecraft and launch vehicles. SIC 3769 accounts for all firms primarily engaged in the R&D and manufacturing of guided missile and space vehicle parts and auxiliary equipment, such as airframe assemblies for guided missiles and spacecraft, bellows assemblies for missiles, casing for missiles and missile components, guided missile nose cones, space capsules, and any other equipment needed to complete the development and manufacturing of spacecraft and launch vehicles. SIC 3662 accounts for the development and manufacture of various forms of ground equipment needed to control and communicate with both the spacecraft and launch equipment described above.

In three of the four SIC industries--3761, 3764, 3769--all of the five-digit product classes listed by the Standard Industrial Classification Manual were identified with space related products. In only one SIC four-digit industry, 3662, they could not. In fact, based on total dollar value

of product shipments in 1982, only 77.3 percent of 3662's total shipments could be classified as space-sector related, and even less, only 19.3 percent could be classified as direct space products.

Table V

Five-Digit Product Classes And Their Repsective
Four-Digit Industries Applicable To the Space Sector

3761 GUIDED MISSILES AND SPACE VEHICLES

37611	Missile Systems, Excluding Propulsion
37612	Space Vehicle Systems, Excluding Propulsion
37613	Research & Development on Complete Missiles
37614	Research & Development on Complete Space Vehicles
37615	All Other Services on Complete Missiles & Space Vehicles

3764 SPACE PROPULSION UNITS AND PARTS

37645	Complete Missile or Space Vehicle Engines and/or Propulsion Units
37646	Research and Development on Complete Missiles or Space Vehicle Engines and/or Propulsion Units
37647	All other Services on Complete Missile or Space Vehicle
37648	Missile and Space Vehicle Engine and/or Propulsion Unit Parts and Accessories

3769 SPACE VEHICLE EQUIPMENT, NOT ELSEWHERE CLASSIFIED (NEC)

37692	Missile & Space Vehicle Parts & Subassemblies, NEC
37694	Research & Development on Missile & Space Vehicle Parts & Components, NEC

3662 RADIO AND TELEVISION COMMUNICATION EQUIPMENT

36621	Communication Systems & Equipment, Including Space Satellite Communications Systems
36625	Search & Detection Systems and Navigation & Guidance Systems & Equipment

(Note, these space related products are all those listed under the five-digit SIC codes identified above. Specific space products are those clearly identified as space systems under the seven-digit SIC product codes. For this study they include: Space satellite and communications systems, telemetering systems and equipment, airborne and missile/space tracking radar systems, missiles and space vehicles systems and equipment, missile-borne and space-borne equipment, non-missile and space vehicle guidance equipment, electronic checkout and other missile and space vehicle support systems) (17).

Ideally, it would be beneficial for this study if the U.S. Department of Commerce broke out SIC 3662 to account for just space sector equipment. In fact, Mr. Tim Shey, director of the Department of Commerce Telecommunications Office, has suggested specifically that space ground stations be identified as a separate five-digit product class (63). Nevertheless, reaction to such a suggestion takes times. Meanwhile, most information concerning space products in SIC 3662 is entangled with other non-space related communications equipment. For purposes of defining the Space sector in this study, information on SIC 3662 will be broken out according to five-digit product classes whenever available. When this breakout is not possible, information will be corrected to reflect a 75 percent value. This value is commensurate with the percentage of SIC 3662's total dollar value of shipments of space-related products.

In addition to understanding what industries are classified as producing space products, it is just as important to realize that not all space products are totally produced by the four SIC industries identified above. This happens because the Census Bureau classifies firms on the basis of their major activity in a paticular year. It is possible for firms in an industry to produce another product (a secondary product) in addition to producing their primary product. An example would be a firm listed in the Aircraft industry (SIC 3721) that, in addition to producing aircraft, also produced spacecraft. Thus, if a true evaluation of the Space sector's industries is to take place, it is necessary to check the industries identified above (SIC 3761, 3764, 3769, 3662) to make sure they only produce the majority of space-related products. To accomplish this, all other industries producing space-related products are identified, and their impact on the Space sector is evaluated. Impact is evaluated utilizing the coverage ratio of the primary industries. The coverage raito is the ratio of the dollar value of primary products shipped by all firms classified in that industry to the total dollar value shipped of primary products by all firms regardless of what industry they are classified in. A high coverage ratio will identify those industries that produce the majority of their products, while, conversley, a low coverage ratio will indicate those industries where a majority of their products are being

produced in other industries. (Note: this author is unaware of any literature that quantifies exactly what a "high" "or "low" coverage ratio is; nevertheless, this study will assume a high coverage ratio to be when the primary industry produces approximately eighty percent of its products (i.e., 80%), and a low coverage ratio to be when other industries produce about the same amount as the primary industry (i.e., 50%).

Table VI identifies all of those industries that actually produce more than $5 million (current year dollars) of space-related products. At first it would appear that the Space sector encompasses much more than just the four industries identified above (SIC 3761, 3764, 3769, 3662).

Table VI

Industries That Produce Space Related Products*

Product: Guided Missiles and Space Vehicles
Producers: SIC 3761 Guided Missiles and Space Vehicles
3764 Space Propulsion Units and Parts
3769 Space Vehicle Equipment, n.e.c.
3662 Radio and TV Communications Equipment
3721 Aircraft
3724 Aircraft Engines and Engine Parts
3728 Aircraft Equipment, n.e.c.

Product: Space Propulsion Units and Parts
Producers: SIC (same as those above)

Table VI cont.

Industries That Produce Space Related Products

Product: Space Vehicle Equipment n.e.c.		
Producers: SIC	(same as those above plus)	
	3452	Bolts, nuts, rivets, and washers
	3842	Surgical appliances and supplies
Product: Radio and TV Communication Equipment		
Producers: SIC	3662	Radio and TV Communication Equipment
	3761	Guided Missiles and Space Vehicles
	3764	Space Propulsion Units and Parts
	3769	Space Vehicle Equipment n.e.c
	3651	Radio and TV Receiving sets
	3661	Telephone and Telegraph Apparatus
	3357	Nonferrous wire drawing and insulating
	3483	Ammunition
	3535	Conveyors and conveying equipment
	3573	Electronic computing equipment
	3574	Calculating and accounting machines
	3579	Office machines
	3622	Industrial controls
	3634	Electric housewares and fans
	3671	Electric tubes
	3674	Semi-conductors
	3679	Electric component n.e.c.
Product: Radio and TV Communication Equipment cont.		
Producers: SIC	3699	Electrical equipment and supplies
	3714	Motor vehicle parts and accessories
	3721	Aircraft
	3728	Aircraft equipment n.e.c.
	3811	Engineering and scientific instruments
	3823	Process control instruments
	3825	Instrument to measure electricity
	3829	Measuring and controling devices
	3832	Optical instruments and lenses
	3842	Surgical appliances and supplies

Source 16; 17

* As discussed above, SIC 3662 produces much more than space related products. Thus, the listing of some 27 industries that produce SIC 3662's primary products is not a fair

representation of those industries that produce just SIC 3662's space-related products. Nevertheless, based on the information available, this is as detailed as this author can go.

Table VI does not take into account the magnitude of each industry's contribution--that is where the coverage ratios come in. Careful analysis of the coverage ratios in Table VII shows that only the products in SIC 3769 are being produced in large enough quantities outside of the primary industries to warrant attention. In fact, in 1982, 54 percent of SIC 3769 shipments of space products were accounted for by other industries. Yet, 25 percent was actually accounted for by the other three industries so far identified in the Space sector (SIC 3761, 3769, 3662). Almost all of SIC 3764's remaining shipments of primary products were accounted for by the Aircraft Equipment industry (SIC 3728)-- a total of 24 percent. If this amount of shipments is compared with the total amount of shipments for all space-related products, it would account for less than 40 percent. Due to the minimal impact this small percentage would have on the entire Space sector, the Aircraft Equipment industry will not be considered as part of the Space sector. Thus, based on an analysis of who actually produces the majority of space products, the Space sector is composed of SIC industries 3761, 3764, 3769, 3662.

Table VII

Coverage Ratios for Space Sector Industries

Industry		Coverage Ratio
Guided missiles and Space Vehicles	1982	86%
	1977	91
	1972	95
Space propulsion units and parts	1982	89
	1977	88
	1972	87
Space vehicle equipment n.e.c.	1982	46
	1977	NA
	1972	NA
Radio and TV communications equipment	1982	91
	1977	92
	1972	91

Source: 16; 17

In order to gain a proper understanding of what today's Space sector is, it is equally important to understand what it is not. As evidenced above, all space products are not produced by one omnipotent industry: the 'Space industry'. Nothing could be further from the truth. In fact, reference to a 'Space industry' that encompasses all space-related products is misleading since all space related products cannot be considered as direct substitutes for one another. What most people are referring to when they use the term 'Space industry', is usually just the Spacecraft industry--one leg in the triad of our Space sector.

Another misunderstanding is that the Space sector is synonymous with the term Aerospace industry--it is not. The

term aerospace was developed in the late fifties when the Aircraft Industries Association (AIA) changed its name to Aerospace Industries Assoc.. This was an effort to reflect the "industry's new role as the supplier of vehicles and equipment for space exploration" (8:154). In fact, most of the companies that produce space products today are an outgrowth of the major aircraft and electronics producers. Since then, all space-related industries have generally been listed under the heading "Aerospace industry". However, the production of space products is very specialize and separate from the production of aircraft. Thus, the Aerospace industry produces more than just space related products. According to the AIA, the Aerospace industry is composed of five more SIC industries (3721 Aircraft; 3724 Aircraft Engines and Engine Parts; 3728 Aircraft Parts and Auxiliary Equipment, NEC; 3811 Engineering and Scientific Instruments; and 3829 Measuring and Controlling Devices) and numerous more five-digit product groups (1:12). In fact, according to the U.S. department of Commerce, the value of missile and space shipments in 1984 accounted for only 21 percent of the total aerospace industry shipments. The term "Aerospace industry" itself is a misnomer. Based on the cursory discussion of industrial organization above, it is evident that any grouping of various industries should be labeled a sector. Thus, the term "Aerospace industry" would better be represented by "Aerospace sector".

Major Buyer/Supplier Relationships

The next step in defining the Space sector is to identify all major buyer/supplier relationships that exit for space products. This is nothing more than identifying who buys what space products from whom; more importantly, it provides an understanding to the nature of the space product market. The first part of this section will iden+ fy the major buyers of space products. Buyers will be identified in terms of the total percentage of sales of those industries that comprise the Space sector. The second part of this section will identify the major suppliers of the space products identified in chapter two of this study.

Major Buyers of Space Products. The most prominent relationship that exists is between the Space sector and the U.S. government. (Included in the U.S. government is the Department of Defense (DoD), National Aeronautics and Space Agency (NASA), Department of Energy (DoE), and the Department of Commerce (DoC).) Based on census data for the years 1978 thru 1983, the government accounted for about 90 percent of the total shipments from SIC industries 3761, 3764, and 3769. Classical economics defines this type of situation as a monopsony-- a situation where there is just one buyer. It would appear from the percentage of government shipments from SIC 3662--which averaged only only 52 percent (16; 17)--that the government was not the only major buyer. However, this figure was derived based on the entire four-digit industry 3662--the only information

available. As mentioned earlier, very few of the products in this industry are actual space products; however, a larger amount have been classified for this study as being space related. It is necessary to adjust this 52 percentage figure to take into account only the space related products sold to the government. If we assume that specific five-digit products in SIC 3662 (alarm systems, traffic control electronic equipment, broadcast and studio electronic equipment, and miscellaneous electronic equipment) are purchased mainly by private consumers, and not the government, then the base from which total government shipments is compared to is reduced by an estimated 25 percent. The new average of government purchases from SIC 3662 would than increase to approximately 70 percent--much closer to the condition identified above with the other industries. (See Table VIII for a complete listing of percentages.)

Of the four government agencies listed above, the DoD and NASA are, by far, the largest consumers of space products. Based on census data, DoD and NASA, between 1978 and 1983, purchased 80 percent of the total value of government shipments from SIC 3769 and 3662, and over 90 percent of the total of government shipments from SIC 3761 and 3764 (16; 17). This data coresponds directly with the percentage of total federal space outlays of both the DoD and NASA between 1978 and 1984. During this time both

agencies spent more than 97 percent of the government's total space activities outlays (1:70).

Table VIII

Percentage of Toatal Shipments Purchased by the Government from the Space Sector

Industry (SIC)	78	79	80	81	82	83	Avg
3761	92	93	89	91	91	92	92
3764	87	94	92	96	95	92	93
3769	87	81	84	94	96	95	89
3662	54	50	51	51	52	58	53
3662 Adjusted	71	66	68	68	70	77	70

Source: 21; 22; 23; 24

Military Space Activities. The military's involvement in space began during the 1940's when both the Navy and the Army Air Corps performed conceptual studies to evaluate how space might be useful in conducting military operations. These studies were very visionary, and identified four of the five military missions performed in space today; communications, reconnaissance, surveillance, and meteorology. The only use it failed to identify was navigation (8:37-8). (See Table IX for or a complete listing of the DoD's current spacecraft by mission.) Of the five missions, communications is by far the most dominant. Between fiscal years 1982 and 1984, the DoD spent as much on the communications missions as the other four put together; and based on estimates for fiscal years 1985 and 1986, this trend looks as if it will continue (1:77).

Table IX

Current Military Spacecraft by Function

Communications	Reconnaissance/Surveillance
DSCS-2	Broad Coverage Photo Recon
DSCS-3	KH-11 Stategic Recon
FleetSatCom 1-8	Ocean Surveillance 1
Satellite Data System	Defense Support Program
Leasat	Ferret
**Milstar	Clipper Bow
	CRRES
Navigation	SCATHA
Nova	P-78-1
Navstar/GPS	
SOOS	
	Meteorological
	DMSP

** Systems not yet deployed

Source: 57:172

However, these mission orientated uses of space make up only a little more than a quarter of the total amount the DoD spends on space and space-related programs (1:79). The DoD spends the rest of its money on vehicle development, space ground support (which includes range support, instrumentation, ground based satellite detection, tracking and control), supproting R&D, and general support. The largest of these is by far general support, which includes support organizations, as well as general operational support. General support accounts for approximately 40 percent of DoD's total space expenditures.

NASA Space Activities. NASA, the other major source of government space expenditures, was created by the

National Aeronautics Space Act of 1958, with the intention of preserving the U.S. as a "leader in aeronautics and space science and technology" (31:31). From its launching of Echo 1, a communications balloon used to relay radio signals across intercontinental distances in August of 1960, to today multi-operational Space Shuttle, NASA has nurtured and regulated private industry in space.

Today, NASA faces internal disputes about its future role in space. Some argue that NASA should strickly be a research and development agency, and leave space operations to commercial interests. Others feel that NASA should continue its role as an operational organization (31:48). Which direction NASA goes in the future will have a direct impact on both the type and quantity of space products it purchases. However, until that decision is made little more than speculation is appropriate.

Currently, NASA spends a majority of its budget, 65 percent in 1984, on space operations. NASA's space operations is composed of shuttle production and operational capability, space transportation operations (both shuttle and expendible launch vehicles), and space/ground network communications and data systems (1:77). The remainder of NASA's budget is spent on research and development--everything from tracking and data advanced systems to commercial use of the space station. (See Table X for a complete listing of current NASA spacecraft by function.)

Table X

Current NASA Spacecraft by Function

Communications	Remote Sensing
TDRSS	Landsat 4
**ACTS	Dynamics Explorer
	**GRO
Meteorological	**International Solar Polar
NOAA	Solar Mesosphere
GEOS	AMPTE-CCE, RM, UKS
TIROS	ERBS
	**COBE
Exploration	**URAS
Voyager	
Galileo	
**Hubble Space Telescope	
Mariner	
Viking	

** Systems not yet deployed

Source: 57:172

Commercial Buyers. The government is not the only buyer of space products. Private firms have also ventured out into space, though, as the figures above reveal, not with the same enthusiasm. Nevertheless, commercial interest in space is alive and indications are they are growing in three specific areas: communications, remote sensing, and manufacturing.

Communications. Communications by satellite is by far the largest commercial space business. The first pseudo private company, Comsat, was created by the Communications Act of 1962. Comsat was a public/private company responsible for telecommunications and broadcast satellite servicing to North America (53:88). In just two

short years Comsat went public and issued stock. In 1970 Comsat showed its first quarterly net operating profit and proved space was a worth while commercial venture (31:59). Since that time many other corporations have joined the band wagon and started their own space operations. At the end of 1983, 19 civilian and private satellites were in service. Of the 19 saellites RCA, Western Union, and Comsat each owned four; IBM owned three SBS satellites; Hughes operated two Galaxy satellites; and AT&T has two Telstar systems (53:22-24). Companies, however, do not have to own their own satellites to participate in the market. Instead, companies can lease or purchase transponders from the satellite owners. HBO, MTV, and CNN have been the big purchases of these transponders (31:66). (See Table XI for a complete breakout of companies that own satellites and other companies that are breaking into the space communications business.)

Today the American domestic space communication market is the largest in the world; however, it has not always been booming. In 1984 a FCC investigation showed 42 percent of the transponders were not in use--up from 33 percent two years earlier. However, new ideas are constantly emerging to take up the slack. Today mobile satellites (MSATs)--a proposed new communications system that would allow two-way mobile services via satellite, and direct broadcasting satellites (DBS)--satellites that due away with cable

companies by broadcasting directly into each home are the new ideas for the next decade.

Table XI

U.S. Domestic Carriers

Companies That Own Satellites	Satellite
Western-Union	Westar
RCA	Satcom
Comsat	Comstar
IBM	SBS
Hughes	Galaxy
AT&T	Telstar
GTE	G STAR
Spacenet	Spacenet

Companies That Plan to Own Satellites
Advanced Business Com.
Rainbow Satellite
US Satellite System
Ford Satellite Services
National Exchange
Alascom
Columbia Communications
Equatorial Communications Serv.
Federal Express
Martin Marietta

Source: 53:24

Remote Sensing. Remote sensing satellite where developed about the same time as communication satellites. Unlike the wide variation of communication satellites, most services to date have been performed by LANSAT. LANSAT is a series of satellites operated by the National Oceanographic and Atmospheric Administration (NOAA) of the Department of Commerce (53:91). Up to this point,

remote sensing has proved to be unprofitable. The reason for this is that most of the information has been regarded as a public good. Thus, individuals that benefit from its information are not always charged; nevertheless, this trend is changing with the offering of new services. Current schedule is for LANSAT to be transferred over to public enterprise by 1989 (31:81). Various companies have already shown interest in operating the weather as well as the earth resource satellites: Comsat, RCA, General Electric, Lockheed, Bendix, and Computer Sciences Corp. (31:84).

Manufacturing. Unlike communications and remote sensing, space manufacturing is in its infancy. Presently, most purchases of space products to carry out space manufacturing is done by NASA. Nevertheless, many corporations are already showing great interest in this area. McDonnell Douglas, through a Technical Exchange Agreement (TEA) with NASA, was able to test out the continuous flow electrophoresis for manufacturing pharmaceuticals in space (31:98). Still other like Corning Ware, Coors Brewing Company, Dow Chemical, Dupont, and Ford Motor company have sent manufacturing experiments in space via the Shuttle (31:90). Though there is no real demand for space products from private industry to carry out space manufacturing, it is only a matter of time before launch vehicles and spacecrafts are needed to ferry materials across vast distances.

Major Suppliers of the Space Sector. Equally important as understanding who buys space products is knowing exactly what firms are producing them. The purpose of this section is to identify the nucleus of the firms participating in the production of spacecraft, launchers, and ground equipment.

Spacecraft. Spacecraft are very technologically advanced pieces of equipment. The high risk and cost associated with the new investment required to produce such specialized products have fostered an environment where only a handful of firms are prime contractors for the assembly of spacecraft. (See Table XII for a complete list of the firms and their spacecraft.) Because these spacecraft are so complex, many components and subsystems are subcontracted to other companies. On a major contract 40 to 70 percent of the work will be let out (31:106). A perfect example is Rockwell, the prime contractor for the Space Shuttle. Rockwell contracts out to over 40 companies for shuttle systems--see Appendix I for a complete list. Many of these companies are usually either independent concerns or subsidiaries of the prime contractor.

Production is so specialized that many of the prime contractors specialize into specific spacecraft products. Ball Aerospace, the smallest of all the firms, produces mainly scientific satellites for the DoD. Fairchild, though not a direct producer of satellites, is heavily involved in space subsystems and space platforms. Ford Aerospace holds a modest share of the U.S. commercial satellite market, and

in addition, also places a high priority on co-operative projects with foreign countries. General Electric depends heavily on NASA's business for earth resource satellites like LANSAT. In fact, in 1984 they were NASA's fifth largest money contractor with over a quarter billion dollars in prime contract awards. Grumman Aerospace, relatively new to the Space sector, is heavily involved with the DoD in the development of the space station. Hughes is the overall leader in satellite sales, and in 1984 had thirty percent of the U.S. civilian communications market. Lockheed and TRW, on the other hand. produce almost entirely defense reconnaissance and communication satellites. Martin Marietta Corp., like Fairchild, does not manufacture any complete spacraft; however, Fairchild is involved in the production of spacecraft instruments and equipment. Rockwell, identified earlier in this study, recently won the award for twenty-eight Global Positioning Systems (GPS) navigational satellites, the largest number of satellites ever awarded under one contract. Finally, RCA specializes in the production of meteorological satellites, and in the future will apply much of their resources to communications satellites, specifically direct broadcast services.

Table XII

Spacecraft Manufactures

Ball Aerospace Systems
- AEROS (scientific)
- CRRES (scientific)
- ERBS (scientific)
- P-78-1 (scientific)
- Solar Mesophere Explorer

General Electric
- DSCS-2 (comm)
- Landsat 4 (remote sensing)
- URAS (remote sensing)
- Nimbus (remote sensing)

Hughes Space & Comm Group
- Westar (comm)
- Marisat (comm)
- Comstar (comm)
- SBS (comm)
- Telstar (comm)
- Satellite Data System (comm)
- Leasat (comm)
- Galaxy (comm)
- GEOS (meteorological)

RCA Corp.
- ACTS (comm)
- Spacenet (comm)
- G STAR (comm)
- Amersat (comm)
- Americom (comm)
- STC/DBS (comm)
- Gstar (comm)
- NOAA (meteorological)
- DMSP (meteorological)
- Tiros (meteorological)
- Nova (navigational)
- SOOS (navigational)

Boeing Co.
- Mariner
- SAGE (scientific)

Fairchild Space Co.

Ford Aerospace
- DBCS-2 (comm)
- Fordsat (comm)
- NATO III (comm)

Grumman Aerospace Corp.

Lockheed Missiles & Space Co.
- MIDAS (surveillance)
- Ferret (surveillance)
- SAMOS (surveillance)
- Space Telescope
- Teal Ruby (scientific)

Martin Marietta Corp.
- SCATHA (scientific)
- Viking (scientific)

Rockwell International Corp.
- Space Shuttle Orbiter
- GPS (navigation)

TRW
- TDRSS (comm)
- DSP (surveillance)
- DSCS II (comm)
- FleetSatCom (comm)

Source: 8; 53; 67:

In addition to the firms described above, there are various research organizations that also particpate in the development and construction of spacecraft. Lincoln Laboratories of MIT, Jet Propulsion Lab of Caltech, Applied Physics Lab of John Hopkins, and the Naval Research Lab are all major organizations that have built spacecraft for purely scientific purposes but have never competed for commercial or operational military systems (8:54). Even though their efforts could be useful in times of drastic increase production, none of these organizations will be considered as part of the Space sector in this study.

Launch Vehicles. Launch vehicles, as described in chapter two, are generally developed and manufactured by a primary contractor who is also responsible for the launching of the vehicle (53:42). In addition, there are a few major subcontractors who are responsible for the development and manufacturing of engines and fuel. Table XIII lists the major primary contractors and subcontractors associated with both launch vehicles and upper stages. Rockwell has been one of the largest dollar producers of launch vehicles. As prime contractor for the Space Shuttle, Rockwell was awarded over 1.4 billion dollars from NASA alone in 1984 (67:1505). Martin Marietta remains active in the launch business as the prime contractor for the Titan booster and Transtage upper stage (20:37-10). General Dynamics is still producing Atlas launch vehicles, and in the past has manufactured the

Centaur upper stage. McDonnel Douglas, though no longer producing Delta rockets, is the prime contractor for the PAM upper stage. Boeing, also manufacturing upper stages, is the prime contractor for the IUS. Morton Thiokol, Aerojet, Rocketdyne, TRW, and Pratt & Whitney are all major subcontractors that supply solid and liquid rocket engines and fuel for launch vehicles.

Table XIII

Major Primary and SubContractors for Launch Vehicle Production

Rockwell Int. Corp. Space Shuttle Orbiter	McDonnell Douglas Corp. Delta Launcher PAM Upper Stage
Boeing Co. IUS Upper Stage	Martin Marietta Corp. Titan Launcher Space Shuttle Propulsion Transtage Upper Stage
General Dynamics Corp. Atlas Launcher Centaur Upper Stage	Aerojet General Titan Propulsion Delta Propulsion Transtage Propulsion
Morton Thiokol Space Shuttle Propulsion Delta Propulsion Scout Propulsion PAM Upper Stage Propulsion Delta Upper Stage Propulsion	Rocketdyne Division Atlas Propulsion Delta Propulsion

Source: 67

<u>Ground Equipment</u>. Unlike spacecraft and launch vehicles, there are quite a few firms that manufacture ground equipment. Table XIV lists the major manufactures of ground stations and equipment used in the telemetry,

tracking, and control of spacecraft and launch vehicles.

Table XIV

Major Ground Equipment Firms

Advance Systems Concepts	Aydin Satellite Comm.
B-Scan Inc	Comtech Antenna Corp.
Datron System, Inc.	Decom Systems, Inc.
Electrocom Automation Inc.	Electronic Space Systems
Fairchild Comm. Co.	Fairchild Weston Systems
Fenwal Inc.	Ford Aerospace & Comm Corp.
General Dynamics Corp.	Global Comm. Corp.
Gould Inc.	GTE Corp.
Harris Corp.	IBM's Federal Systems Div.
ITT Corp.	LNR Comm. Inc.
Magnavox Co.	MCL, Inc.
Metraplex Corp.	Mu-Del Electronics, Inc.
Satellite Systems, Inc.	Sonex Corp.
Scientific Atlantic	Tele-dynamics
Systems Technology, Inc.	Union Chill Mat Co.
TRW Inc.	Western Geophysical Co.
Vega Precision Labratories	

Source: 31; 53; 67

The firms listed above represent by no means a complete list of the Space sector. There are numerous others U.S. firms that produce various systems, subsystems, components, and equipment for spacecraft and launch vehicles. In addition, there are major producers of space products in Canada, Europe, and Japan. However, in keeping with the limitations of this study, only the U.S. Space sector will be analyzed.

Structural Characteristics

To fully understand the Space sector and its environment, it is necessary to evaluate the structural characteristics of the industries identified above. In any industrial study there are many structural characteristics that can be evaluated. This study will focus on two of the more salient aspects: the extent of barriers to entry, and the degree of seller concentration.

Barriers To Entry. Bain identifies three main sources of barriers to entry in manufacturing industries: economies of scale, product differentiation, and absolute cost advantages (4:255). Economies of scale are basically the ability of firms to manufacture and market a large number of products at a lower unit average cost than if they produced a smaller number of products. This is usually due to advantages gained in the manufacturing process itself. Product differentiation is the ability to distinguish two similar products due to some unique feature in one. The feature can be either physical--better performance--or mental--contrived in the minds of the buyer due to marketing campaigns. Either way, product differentiation "hinges on the degree of substitution among competing sellers" (58:11). The final barrier to entry, absolute cost advantages, pertains to gains one firm has in production and distribution costs over another. Bain list four principle potential bases for such advantages (4:260):

1. Control of superior production techniques by established firms, maintained by patents or by secrecy.

2. Exclusive ownership by established firms of superior deposits of resources required in production.

3. Inability of entrant firms to acquire necessary factors of production (management services, labor equipment, materials) on terms as favorable as those enjoyed by established firms.

4. Less favored access of entrant firms to liquid funds for investment, reflected in higher effective cost or in simple unavailability of funds in the required amounts.

Of the three barriers to entry identified above, both economies of scale and product differentiation have little impact on the overall Space sector. Production runs of spacecraft are still too low for any one industry to gain a major advantage over another. Nevertheless, as the size of contracts for spacecraft and launchers increase, and producers become more aware of the manufacturing advantages of standardizing spacecraft design, the effects of economies of scale will increase. There is one area of the Space sector, however, that is aware of the role economies of scale might play--the firms that manufacturing small earth stations. As satellites get more powerful, due to the advances in microcircuitry and propulsion systems, they will perform more functions that were once the sole responsibility of large earth stations. This transfer of responsibility has the prospect of multiplying the number of small earth stations several thousand times in the next few years. Various firms are studying production runs that

number into the thousands. For example, NEC and M/A-Comm Tellecommunications Div. have a contract to supply Federal Express with small earth stations that could produce sales as high as 30,000 (57:127-128).

Product differentiation, as Bigelow points out, is largely a matter of brand loyalty (8:81). System requirements are so severe, and overall cost factors so high, that most products fight to just keep price as low as possible while obtaining a minimum standard of effectiveness. Nevertheless, as the price of placing a pound of equipment into space declines, opportunities in space will open up and product differentiation will, more than likely, increase as producers find ways have to distinquish their product from the competition.

The most extensive barrier to entry in the Space sector, especially in spacecraft and propulsion industries, is absolute cost advantages associated with producing space products. This is due to the control of superior production techniques, and the high threshold of initial fixed investment costs. Superior production techniques are more than just possesing the factors of production--the machinery necessary to manufacture space equipment. Superior production techniques is also the knowledge of the sophisticated technologies, and the ability to master these techniques. The learning curve for these industries are years, and in the case of launchers possibly decades. Thus, there is a distinct advantage to those industries first in

business. The extent of this barrier is best shown by the high percentage of scientist and engineers that work in the Spacescraft, Propulsion, and Miscellaeous industries. Between 1981 and 1985, scientist and engineers made up over 22.7 percent of the total work force. This compares with an average of 13.2 percent in the Aircraft industry and 11.8 percent in the entire Transportation Equipment sector (1:155; 28:108).

Another factor which effects the absolute cost advantages is the high fixed investment cost associated with the Space sector. This is best understood when one realizes up to now the government has been the only one to bear the excessive initial cost (53:45). This is especially true in the case of launchers where development can run into the billions of dollars. The high start-up cost take the form of extensive test and checkout facilities necessary to evaluate the extreme performance requirements, and acquiring and maintaining the scientific and engineering skills necessary.

Seller Concentration. One of the major effects of substantial barriers to entry is the development of high concentration levels within that industry. Concentration is best described by the number and size distribution of sellers in an industry. It provides a measure of market power and helps classify the industry as either a monopoly, oligopoly, or competition. The most common method of

measuring seller concentration is calculating the percent of total industry sales contributed by the largest few firms (58:56). This is referred to as the market concentration ratio (MCR). Since the MCR is a percentage, its value ranges from zero to one. A value of one indicates that the number of firms the ratio is being calculated for control all the sales in the economy. If a MCR of one is calculated for just one firm then that firm would be a monopoly; consequently, if one was calculated for a small number of firms the industry structure would tend towards an oligopoly. It is possible to develop concentration ratios for other than industry sales. Concentration ratio for capacity, employment, value added, or physical output are a few others which could be easily measured.

A single MCR is like a picture, it provides a static representation of the industry. To provide a more panaramic view, it is customary to report more than one MCR. Usually, MCRs are reported for the top 4, 8, 20, and 50 firms in an industry. For example, if a MCR of 20 percent was calculated for the top firm all that we could be sure is it was not a monopoly. Enough information is not available to determine if the industry is an oligopoly, or possibly a monopolistic competition. If, instead, we also knew the MCR for the top 4 firms was 60 percent, and 100 percent for the top 8 firms we would tend to believe the industry was an oligopoly since few firms control the entire industry. In fact, Shephard, in an article published in the Review of

Economics and Statistics, pointed out that industries with a four-firm concentration ratio above 60 are considered tight oligopolies, especially when characterized by high barriers to entry and a tendency towards cooperation (59:616).

The Department of Commerce calculates the MCR for all major 4-digit industries in a special report, Concentration Ratios in Manufacturing. The most recent edition is based on the 1982 Census of Manufacturing, and was published in 1985. Table XV list the MCR for the 4, 8, 20, and 50 largest firms in the Space sector. In addition, it includes the total number of firms in each industry.

Table XV

Market Concentration Ratio By Industry For The Space Sector

Industry	Firm Size				Total #
	4	8	20	50	
3662----1982	22	35	57	73	2083
1977	20	33	57	73	1873
1772	19	33	58	73	1524
3761----1982	71	96	100	--	16
1977	64	94	100	--	20
1972	62	88	N/A	100	23
3764----1982	68	93	100	--	20
1977	69	93	100	--	18
1972	59	92	N/A	100	22
3769----1982	N/A	N/A	99	100	45
1977	76	86	97	100	41
1972	70	85	97	100	45

Source:18

Table XV confirms much of what has already been said in this chapter--the Space sector is composed of industries with a small number of firms. It also stresses the fact that these firms are highly concentrated, with a tendency towards becoming more concentrated over the years. This is extremely evident in the Spacecraft industry where the top 8 firms controlled 100 percent of total sales. The only exception to this is the Radio & Communications Equipment industry. Howevr, as mentioned earlier, this is due to the industry's broad classification. It is possible to filter out unnecessary information by evaluating the five-digit product class ratios. When concentration ratios are computed for four-digit industries many of the top companies have sales figures that include sales from other areas. This is due to the nature of the reporting system inherent in the SIC codes. Thus, by breaking down the industry to its products, one obtains a clearer picture of the Space sector's concentration. Table XVI list the MCRs for the Space sector's five-digit product classes.

Table XVI

1982 Concentration Ratios for the Space Sector's Product Divisions

Industry	Firm Size 4	8	20	50
36621	38	50	66	81
36625	31	46	72	91
37611	71	93	100	--
37612	83	N/A	N/A	N/A
37613	80	98	100	--
37615	74	87	97	100
37645	68	93	100	--
37646	86	99	100	--
37647	88	99	100	--
37648	49	69	94	100
37692	50	68	87	98
37694	83	95	99	100

Source:18

In almost every case the five-digit MCR was greater than its coresponding four-digit rate. The results still, however, do not reveal the high concentration in the production of large ground stations. In the world market, 75 percent of INTLSAT stations are built by NEC and ITT. The OECD also points out that just a few firms in the U.S. dominate the production of medium-size stations, specifically those in the 4/6 GHZ region (53:45).

The only real move towards a decrease in concentration in the ground station industry is due to increases in satellite power. As satellites get more powerful they will

not have to depend as heavily on ground stations. Thus, ground stations will be less complex and more easy to manufacture. The first sign of this is already present with DBSs. DBSs will open the market for small antennas. However, this will not be an easy road since small companies like Scientific Atlantic already claim 40 percent of the U.S. market (53:45).

Overall, these MCRs, both four and five-digit, paint a picture of a sector that, due to the high barriers of entry, seem very concentrated. The implications of this are immense and worthy of studies themselves. Nevertheless, it is important to realize that when sellers are few and they recgonize their interdependence it is possible, through collaboration, for them to maximize group profits at the expense of the buyer (58:266).

Conclusion

The purpose of this chapter was to develop a working definition of the Space sector to further the quantitative analysis of it surge capacity. The Space sector was broadly defined as "a segment or division of the economy; specifically, those industries that produce a collection of space products necessary to carry out current space operations". Thirteen five-digit SIC product groups were utilized as building blocks to construct four four-digit SIC industries to represent the Space sector. These industries included the Guided Missile and Space Vehicle; Space

Propulsion Units and Parts; Miscellaneous Space Vehicle Equipment; and Radio and Televivision Communication Equipment. Only the last industry, Communication Equipment, did not solely produce space related equipment. In fact, analysis showed roughly 75 percent of its total shipments were classified as space related, and only 20 percent were actual space products.

In identifying the major buyer/supplier relationships, this author found a market extremely dependent on government purchases. In fact, the government accounted for approximately 90 percent of all space products with exception to ground equipment. Although evidence suggests this trend is changing, as more private investors are turning to space for communications, remote sensing, and manufacturing, chances are it will be quite a while--if ever--before the government is replaced as the major buyer.

In addition to facing one major buyer, the Space sector is composed of a small number of large specialized sellers. High risk, associated with technologically advanced equipment, and high fixed investment cost have constructed barriers to entry that have kept the number of firms in the Space sector small.

This oligopolistic stucture, however, is still in the early stages of development. As demands for space products grow, and the technologies that allow man to reach the heavens become more accessible, the Space sector will change to better meet demand. Nevertheless, before one can

determine if the Space sector, or any sector, can change with demand it is important to understand the interactions of the Space sector with itself and the entire economy. The next chapter reviews the use of input-output analysis as a methodology to investigate these interactions.

IV Review of Input-Output Analysis

The previous three chapters described the need to evaluate the lower levels of the industrial base to see if they could support a production surge in the Space sector, and, equally important, defined exactly what the Space sector is, and what it supports. This chapter analyzes input-output analysis as a research methodology to evaluate the impact a surge demand would have on the economy first, in terms of its theory; second, in terms of how its been used in defense studies already; and third, in terms of any limitations that the theory has.

Input-Output Theory

Input-output analysis was developed by Wassily W. Leontief in the 1930's. It is a systematical method of quantifying interrelationships among various components of any economic system (40:19). Since Leontief's first publis ed work, his concept has "launched a quiet revolution that has steadily gained momentum" (46:1). Today, the use of input-output models for economic planning range from small firms to national economies. For purposes of this study, the components of the U.S. economy that are of interest are specific industries, as defined in the previous chapter. Therefore, for the remainder of this chapter, the term "components" will be replaced by "industries" with the knowledge that, in theory, any component of an economy could

be as easily referenced.

Baumol describes input-output analysis as the application of a model that describes a "general equilibrium condition based on empirical analysis of production" (7:537). The model Baumol describes is composed of a Transaction Flow Matrix (Input-Output Table), a Technology Coefficient Matrix and the Inverse Matrix.

The Transaction Flow Matrix (see Fig. 2) describes the supply and demand relationships of an economy in equilibrium. It is nothing more than an eloborate accounting system that records the interaction of all industries and labor with themselves and their contribution to final demand. Reading down the columns, the matrix records how much each j industry purchased from all the i industries in the economy inorder to produce its final product. Purchases include everything from labor (primary inputs) to raw materials to complete subcomponets. Reading across a row, the matrix records how much each i industry delivers to both the j industries, as inputs to their manufacturing process, and the consumers, as final demand. Thus, the output of any industry is either used by other industries in their production process, or is used to satisfy final demand. As Baumol points out, the interindustry transaction matrix is nothing more than an alternative way to present N simultaneous linear equations in N variables (7:537). Mathematically, this can be written as:

$$X_i = \sum_{j=1}^{n} X_{ij} + C_i \qquad 1 \le i \le n \qquad (1)$$

$$L = \sum_{j=1}^{n} L_j + W \qquad (2)$$

	Producing Sector: j		
Selling Sector i	Interindustry Transaction Matrix: Xij	Final Demand: Ci	Total Demand: Xi
	Primary Inputs: Lj	Services W	Total Inputs: L

Fig 2. Transaction Flow Matrix (input-output table)
Source: 3; 35; 43.

Where:

Xij = amount of product from sector i used by sector j

Ci = amount of final demand from each sector i, i.e., personal consumption expenditures, private investment, government purchases

Xi = total gross output from sector i, i.e., Xij + Ci

Lj = amount of labor used by sector j

W = amount of labor consumed as a final product, i.e., services

L = total labor consumed, i.e., Lj + W

Two of the most elaborate Transaction Flow Matrices are developed by the Bureau of Economic Analysis (BEA) for the entire U.S. economy. The first one is the 'Use Table'. It shows the dollar value of each commodity used by each industry in the economy. The second one is the 'Make Table'. It shows the dollar value of each commodity produced by each industry in the economy (35:48). These tables are based primarily on detailed industry statistics collected by the Census Bureau. Since the tables are dependent on census data, they are only developed once every four years. BEA has developed a total of six tables to date: 1947, 1958, 1963, 1967, 1972, 1977 (35:42).

The information in the Transaction Flow Matrix can be used to determine both the Coefficent Matrix and the Inverse Matrix (3). The Coefficient Matrix is composed of technical coefficients, A_{ij}, that show the amount (value) of output product i required as an input to produce one unit (dollar) of product j (56:267). The Coefficient Matrix is derived by dividing each value in the Interindustry Transaction Matrix, X_{ij}, by it respective X_j, the total value produced by industry j. (See eq. 2).

$$A_{ij} = X_{ij} / X_j \qquad (2)$$

Thus, the Coefficient Matrix is just a modifided Interindustry Transaction Matrix with A_{ij} as a measure of the interdependence between any two industries in the

economy. The larger the value of Aij the more industry j depends on industry i. A good example of a Coefficient Matrix is the Direct Requirement Table (DRT) developed by the BEA. This is a very detailed table that shows the direct dollar input required from 534 industries to produce one dollar worth of each 526 commodities in the U.S. economy.

The inverse matrix is nothing more than an algebraic manipulation of the information already presented. If eq. 2 is solved for Xij and substituted into eq. 1, the system can be defined as:

$$X_i = \sum_{j=1}^{n} A_{ij} X_j + C_i \qquad 1 \leq i \leq n \qquad (3)$$

$$X_i - \sum_{j=1} A_{ij} X_j = C_i \qquad 1 \leq i \leq n \qquad (4)$$

If eq.(4) is rewritten in vector notation:

$$X - AX = C \qquad (5)$$

$$(I - A) X = C \qquad (6)$$

where

$X = X_i$ (The total output vector)

$$Ax = \sum_{j=1}^{n} A_{ij} X_j$$

$C = C_j$ (The final consumption of goods)

Solving for X:

$$X = (I - A)^{-1} C \tag{7}$$

where

$(I - A)^{-1}$ = the Inverse Matrix

The unique feature of the Inverse Matrix is that it solves directly for the total output (Xi) required of any industry in response to the final consumption (Ci). (Total output is both the direct and indirect demands placed on that industry.) The benefit of the Inverse Matrix is it can be used to do sensitivity analysis and evaluate how changes in final demand (Ci) effect each industry's total output (Xi). A good example of an Inverse Matrix is the Total Requirements Table (TRT) developed by the BEA. Like the DRT, the TRT is a very detailed collection of interactions between the various commodities and industries throughout the economy. However, instead of showing just the direct dollar input required to produce one dollar of some commodity, the TRT shows the total dollar required--both direct and indirect--to produce one dollar of some commodity. Thus, by knowing how much final demand (Ci) changes for a specific commodity, like spacecraft, and by knowing the total requirements for each industry that help produce spaccraft--either directly or indirectly--it is possible to determine the overall effect on the economy in response to a change in the final demand of spacecraft.

Assumptions. Inherent in the use of input-output analysis are three fundamental assumptions. The first assumption is that no two products are produced by the same industry (7:538). Thus, only one industry can produce a specific product. The BEA, in producing their input-output tables for the U.S., classifies industries in accordance with the Standard Industrial Classification (SCI) system mentioned earlier in this study (35:51). Specifically, the BEA produces input-output tables that reflect both the three, and four-digit levels (35:52).

The second assumption is that all industries are performing efficiently (3). This assumption appears viable if the economy is competitive and inefficient firms are forced out of business. Yet, the U.S. is not totaly competitive, and monopolies do exist. Schrere points out that inefficiencies in U.S. monopolies alone account for cost society the equivalent of 6 percent of the gross national product. This figure is not laid in concrete however, since there is a reange of uncertainty from 3 to 12 percent. Arguments have also been made that monopolies offer off setting benefits in the form of security, research and development, and stability in the market place. Yet, Scherer stresses the fact that these benefits are a "good deal smaller than the burdens impossed by monopolistic conduct" (58:470). Thus, while there are some inefficiencies scattered throughout the economy, their impact on a model of the entire U.S. economy has to be

considered small.

The third assumption is that the ratio of inputs used in production are employed in fixed proportions. This is referred to as fixed proportion production, and means there is no substituting one input for another in the production of a final good. For example, if production of some good had to be increased threefold, all its existing inputs would be increased threefold. Thus, no allowance is made for substitution between current inputs or alternative inputs. This assumption is probably the weakest of all three. It is hard to imagine that a firm faced with changing demands would not consider alternative production techniques. In reality, industries would use inputs up to the point where the ratio of marginal product to price is equal for all inputs.

Input-Output Analysis In Defense Studies

One of the first uses of input-output analysis in evaluating defense expenditures was performed by Leontief and Hoffenburg (42:47-55). The purpose of their study was to estimate the effect an arms cut would have on the industrial distribution of the labor force for the whole country (43:217). Their database was the 1947 U.S. Input-Output Tables. These tables were modified to reflect the direct and indirect demand by industries both on products produced and man-years employed. The authors proportionally transferred twenty percent of the military budget to other

demand categories, and then calculated the effect it would have on employment levels in specific sectors. However, when dealing with employment issues, an aggregate approach of this sort fails to take into account impact on individual regions and localities (55:142). Yet, many specific defense sectors, like the Space sector, are regionally located. Thus, any analysis in defense expenditure changes should take regional differences into account.

In a follow on study, four years later, Leontief and his co-authors evaluated the effect a cut in military expenditures would have on industrial composition and regional distributions of employment (41:217). This study proceeded in exactly the same manner as Leontief's first study, except the country was divided into 19 regions, and products were classified as either 'National' or 'Local' (43:219). Unlike the first model, this one could identify the effects a change in government expenditures would have on both specific industries and/or regions.

The final study reviewed was Michael Miller's Measuring Industrial Adequacy for a Surge in Military Demand (47). This study was more in tune with the problem of evaluating the Space sector's ability to respond to a production surge, and forms the foundation for this study's approach. In carrying out his study, Miller followed the same procedure as Leontief. Using current input-output tables of the U.S.

economy, Miller developed an input-output model to evaluate the effect doubling production would have on 13 critical defense industries. First, Miller used the Transactional Flow Matrix to determined that a surge in any or all of the 13 industries caused a response in 354 other industries (47:13). Further subjective analysis reduced the total number of vital defense suppling industries down to 99 (47:13-14). Potentially vulnerable industries were identified through input-output analysis by comparing the current capability of each industry with the effects defense expenditures had on the 99 industries (47:15).

These articles were classic examples of input-output analysis applied to defense issues. And though the specific results are not important to this manuscript, their implications are. By employing input-output models like these, the government could identify any major changes in product flow and employment due to changes in defense expenditures.

Input-Output Limitations

Based on the assumptions discussed above, there are limitations to the three models presented here and any input-output model. The major problems are data limitation and interpretation. How do you know exactly what industries are going to be directly impacted by some government action? In both of Leontief's studies the answer was easy. Since both dealt with an overall reduction in all defense expenditures, the sectors affected were easily identified by

reading them right off the input-output tables. In Miller's study the job of identifying the affected sectors was more involved. The 13 critical defense sectors were chosen according to qualitative assessment of 94 defense-oriented industries identified from a Bureau of Census list (47:10-13).

Even more unique is the problem data limitation causes when dealing with the specific defense sector. Information on what industries make up the sector can be sorted out from contractual information; however, most of the data available relates to prime contractors (55:148). Richardson points out that when dealing with the Space sector, "The high incidence of subcontractors in defense-space manufacturing makes it particulary dfficult to trace through the interindustry flows without a detailed survey of the subcontractors themselves." (55:148). As if this problem is not enough, many of the contractors operate in more than one industry. So exactly what is their SIC listing and where BEA places them on the U.S. Economy Input-Output Tables is questionable.

Another problem of data limitation is how current the information in the input-output tables are. Since the BEA develops these tables from census data, they are only produced every four years. Thus, when dealing with defense related products, which are on the cutting edge of technology, current tables might not reflect the true . . . Miller tried to work around this problem by using the

AD-A180 260 AN ANALYSIS OF THE SPACE SECTOR'S SURGE CAPACITY AN INPUT-OUTPUT APPROACH(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF ENGI.. W K MURPHY 2/3

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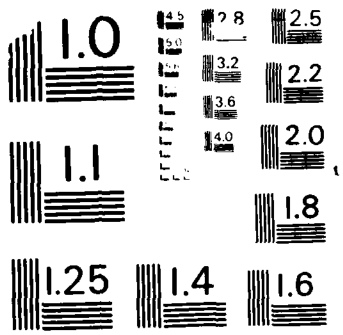

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

separate tables: 1963, and 1967. This provided him a solution based on a range that could be judged against the environment (in his case the Vietnam War), and technological advances.

Conclusions

In evaluating input-output analysis, this author found that it is a model that can represent the interactions of an economy in a series of simultaneous equations. The model itself is based on a few simplifying assumptions which limit the validity of the model. Even with the difficulties of data limitation and interpretation, input-output analysis still provides a viable method for estimating changes in defense expenditures (55:149) and provides a foundation for "quantitatively analyzing an economy in terms of the interdependence of its various industrial sectors" (47:5).

V. Space Sector Dependence

The preceeding chapter presented a brief overview of input-output analysis, and evaluated its validity as a research methodology to determine the impact a surge demand would have on the economy through a review of past defense studies. This chapter is devoted to applying part of that methodology to identify the Space sector's interindustries dependencies. To accomplish this, this chapter first identifies what commodities--at all levels of the economy--are necessary to support a surge in space related products; and second, determines what industries produce them.

Industry Dependency

As Chapter three described, no major space contract is under taken completely by a single firm. Instead, the prime contractor portions out various amounts of work to sub-contractors who are more specialized in some specific field of work. In the case of the space shuttle, 34 firms were listed as associate or sub-contractors (see Appendix I). This same idea holds true for industries as a whole. No industry in the economy operates totally by itself. Every industry is dependent, to some degree, on other industries for their day-to-day operations. The industries that comprise the Space sector are no exception. To support their own production, each industry in the Space sector relies on output from a number of the other 450 industries in the economy.

Dependency between industries can take two forms: direct, or indirect. A direct dependency is when one industry delivers a specific commodity to another industry. An example is when a firm in the Communication Equipment industry delivers a traveling wave guide to a firm in the Spacecraft industry for use in a satellite. Thus, the Spacecraft industry is directly dependent on the Communications Equipment industry. An indirect relationship between two industries is a little less obvious. In fact, it pertains to commodities that might make their way through several different industries before finding their final destination. An example would be the machinery used by the Communication Equipment industry to produce the traveling wave guide for the Spacecraft industry. Though the Spacecraft industry did not buy the machinery directly, its demand for the traveling wave guide created an indirect demand for that machinery. Thus, the Spacecraft industry has an indirect dependency on the industry that produced that machinery. If both the direct and indirect shipments are added together we get a measure of the total dependency of any one industry on another to support a fixed delivery of some final demand. It is this notion of total dependence that is important in determining the surge potential. What really matters is not how much one industry can supply a specific commodity directly to another; but instead, how much of that total commodity can be produced to support production in all sectors that deliver, directly or

indirectly, to any other industry. (More will be said in Chapter VI about the measure of total dependency that exist between the Space sector and the rest of the economy. For now, this chapter just identifies the relationships.)

To identify the various interdependencies that exist in the economy between the Space sector and other industries, the commodities used by the Space sector are first identified. Next, the industries that produce those commodities are determined. To accomplish this, two of the BEA's input-output tables were used (15:V):

> The Use Table: This shows the dollar values of each 'non-negligable' commodity used by each industry in the economy. The BEA Classifies any commodity 'non-negligable' if the total dollar value of the industry purchasing it is less than $100,000 (I-O Def). (For purposes of this study, from now on when the term commodity is used it is understood to mean 'non-negligable' commodity.) In addition, The Use Table also shows the the final sales of each commodity to final users, and the value added originating in each industry.

> The Make Table: This shows the dollar values of production of each commodity produced by each industry. (It is interesting to note that this information is presented two different ways. First, it is shown as 'Industries Producing Each Commodity,' and second, it is shown as 'Commodities Produced by Each Industry'.

In establishing a working definition, the BEA 'utilizes two different classification schemes--industry and commodity--which provides an exhaustive partitioning of the total output of the economy (14:9). The BEA defines each industry as a grouping of establishments by SIC code. Thus, in most cases, there is a direct one-to-one comparison

between the BEA's 537 industries and the Bureau of Census' 450 for-digit SIC industries. The major difference between the BEA and the Bureau of Census is in their classification of commodities. The BEA's also breaks out the production and consumption of 537 commodities. Each commodity corresponds to the "characteristic product of the corresponding Input-Output [BEA] industry" (14:9); however, as the USE and Make Tables point out, a commodity need not be produced by just its corresponding industry. The Bureau of Census, on the other hand, does not partition out specific commodities, and assume just those establishments listed in each SIC industry produces that industry's primary product. Thus, the BEA classification establishes a one-to-one correspondence between each commodities and industry. The end result is a specific matching of an industry to its output. Listed below is the relationship between the BEA's numeric code and the four-digit SIC codes that represent the Space sector:

Table XVII

BEA and SIC Equivalent Codes

BEA	SIC	Description
13.01	3761	Guided Missiles & Space Vehicles
56.04	3662	Radio & T.V. Communications Eq.
60.01	3724, 3764	Aircraft & Missile Engine Parts
60.04	3728, 3769	Misc. Aircraft & Missile Eq.

Even though the BEA classifies its industries in accordance with the SIC classifications there are some problems. The first problem is that SIC 3764 and 3769 are not specifically broken out by themselves. The BEA offers no explanation for this. All this author can assume is that the BEA focused in on just the commodity relationships between industries 3764 and 3724, and 3769 and 3728, and did not take into account the vast differences in each industry's production process. This assumption is based on the one-to-one match-up of the materials consumed by both SIC industries in each BEA classification. That is, SIC 3764 consumes the same material as SIC 3724, and the same holds true for SIC 3769 and 3728 (17; 18). However, just using the same material does not constitute, nor necessitate, the combining of firms into similar industries. As pointed out earlier, this study's working definition of an industry is a collection of firms whose products are direct substitutes for one another, both in consumption and production. Thus, even though these industries consume the same materials that does not mean they have the same production process. Besides, neither industry passes the direct substitute in consumption test. A jet engine may have similar materials as a rocket engine; however, neither product can be substituted for the other--try to fly a satellite with a jet engine!

The second problem has already been mentioned in this study; specifically, that 13.01 (SIC 3662) contains too many diversified products. As pointed out in Chapter three, the industry contains too vast a collection of communication equipment. For example, 13.01 (SIC 3662) contains both space satellite communications systems and railway crossing signals. It would be to the benefit of this study if the industry was broken down into more specific industries to account for the vast product and production differences. Nevertheless, due to a lack of information, the direct effect both these discrepences have on determining the Space sector's interindustry dependencies must be assumed minor.

Commodities Identified

The first step in determining the Space sector's interindustry dependencies was to identify exactly what commodities are used by the four industries identified above. To accomplish this, The Use of Commodities Input-Output table was used. By evaluating each industry, 181 of the total 537 commodities were identified as being necessary for support of the Space sector. Below, Table XVIII lists the ten commodities purchased most by each of the four Space sector industries in 1977 (15). A complete list of all 181 commodities purchased are contained in Appendix B.

Table XVIII

Top Ten Commodities Purchased In Support
Of The Space Sector--By Industry

	Industry	BEA	SIC
	Guided Missile & Space Vehicle	13.0100	3761
1.	Radio & TV Communications Eq.	56.0400	3662
2.	Misc. Aircraft & Missile Eq.	60.0400	3728,3769
3.	Guided Missile & Space Vehicle	13.0100	3761
*4.	Wholesale Trade	69.0100	50--,51--
5.	Other Electrical Components	57.0300	3675-9
*6.	Computer & Data Processing Service	73.0104	737-
*7.	Eating & Drinking Places	74.0000	58--
8.	Sanitary Services & Steam Supply	68.0100	495-,496-
*9.	Real Estate	71.0200	65--,66--
10.	Comm Eq except Radio & TV	66.0000	48--
	Radio & TV Communications Eq.	56.0400	3662
1.	Other Electronic Components	57.0300	5675-9
2.	Semiconductors & Related Devices	57.0200	3674
*3.	Wholesale Trade	69.0100	50--,51--
*4.	Real Estate	71.0200	65--,66--
5.	Radio & TV Communication Eq	56.0400	3662
*6.	Eating & Drinking Places	74.0000	58--
*7.	Personnel Supply Services	73.0104	736-
8.	Plating & Polishing	42.0401	3471
*9.	Electric Services	68.0100	491-
10.	Comm Eq except Radio & TV	66.0000	48--
	Aircraft & Missile Engines.		
1.	Aircraft & Missile Engines	60.0200	3724,3764
2.	Misc. Aircraft & Missile Engines	60.0400	3728,3769
3.	Iron & Steel Forgings	37.0300	3462
*4.	Eating & Drinking Places	74.0000	58--
*5.	Wholesale Trade	69.0100	50--,51--
6.	Iron & Steel Foundries	37.0200	332-
7.	Primary Aluminum	38.0400	3334,2895
8.	Nonferrous Forgings	38.1400	3463
9.	Electrometallurgical Products	37.0102	3313
10.	Misc. Machinery (except electrical)	50.0002	3599

Table XVIII Cont.

<u>Misc. Aircraft & Missile Eq.</u>.

1.	Misc. Aircraft & Missile Eq.	60.0400	3728,3769
2.	Radio & TV Communications Eq.	56.0400	366
3.	Aircraft & Missile Engines	60.0200	3724,3764
*4.	Wholesale Trade	69.0100	50--,51--
5.	Semiconductors & Related Devices	57.0200	3674
*6.	Eating & Drinking Places	74.0000	58--
7.	Aluminum Rolling & Drawing	38.0800	3353-5
8.	Electometallurgical Products	37.0102	3313
9.	Other Electronic Components	57.0300	3675-9
*10.	Hotels & Lodging Places	72.0100	70--

* Corresponds to other than manufactured commodities

Not all the commodities listed above are manufactured. (A manufactured commodity is a "finished product made through the processing of raw or unfinished goods" (37:47).) Instead, some of the commodities identified are produced by other forms of output. BEA classifies these other forms of output into eight categories: Agriculture, Forestry, and Fisheries; Mining; Construction; Transportation, Communications, and Utilities; Wholesale and Retail Trade; Finance, Insurance and Real Estate; and Services. Although a surge in space related products would more than likely result in an increase demand for all types of commodities, only manufactured commodities are focused on in this study. As Miller points out, "measurement of these vulnerabilities [other than manufactured commodities] using input-output

techniques is much less reliable than it is for manufacturing industries (37:14). This is not to say these areas are unimportant. In fact, this country's capability to produce minerals like beryllium and titanium to support the production of space products is an important investigation by itself. Nevertheless, in keeping with the scope of this study, these commodities will not be treated. Overall, 50 commodities produced by non-manufactured industries were identified and were not considered in this study. A complete list is contained in Appendix C.

It is interesting to note the types and quantities of "non-manufactured" commodities that each industry in the Space sector purchased. The most significant was wholesale goods. Wholesale goods refer to both durable and non durable finished goods purchased in wholesale trade. In fact, in all four cases it was one of top five commodities purchased. The other significant non-manufactured commodity was the demand each industry had for "Eating and Drinking Places". Specifically, this refers to various types of food and drink prepared by restaurants, snackbars, and other establishments. In none of the four industries was it less than seventh on the top ten commodity list. This author realizes the need for food and drink by both the employees and management; however, the extremely high demand in this study is suspect and probably warrants further attention.

After separating out all the non manufactured commodities, a total of 130 manufactured commodities are

identified as necessary to support a surge in space products. However, some of these products are not likely to be involved in any kind of surge demand. For the most part these include manufactured commodities used in the peripheral support of the Space sector. Examples include prepared meats, lead pencils and art goods. Which commodities were considered peripheral support is based on the rational that these commodities would have a negligable input into the production of space products, and any increase for these products by the DoD could be easily handled through transfer of commercial production. overall, 39 commodities identified as peripheral support and are listed in Appendix D.

With both non-manufactured and peripheral support commodities accounted for, this study identified a total of 92 commodities critical to support a surge of space products. A revised list of the top ten used by the space sector's industries is shown in Table XVI below. A complete list of all 92 critical commodities is contained in Appendix E.

Table XIX

Top Ten Manufactured Commodities Purchased
By Industry In Support Of The Space Sector

	Industry	BEA	SIC
	<u>Guided Missile & Space Vehicle</u>	<u>13.0100</u>	<u>3761</u>
1.	Radio & TV Communications Eq.	56.0400	3662
2.	Misc. Aircraft & Missile Eq.	60.0400	3728,3769
3.	Guided Missile & Space Vehicle	13.0100	3761
4.	Other Electrical Components	57.0300	3675-9
5.	Sanitary Services & Steam Supply	68.0100	495-,496-
6.	Comm Eq except Radio & TV	66.0000	48--
7.	Misc .Machinery, excluding electrical	50.0002	3599
8.	Carbon & Graphite Products	53.0700	3624
9.	Misc. Plastic Products	32.0400	307-
10.	Motor & Generators	53.0400	3621
	<u>Radio & TV Communications Eq</u>.	56.0400	3662
1.	Other Electronic Components	57.0300	5675-9
2.	Semiconductors & Related Devices	57.0200	3674
3.	Radio & TV Communication Eq	56.0400	3662
4.	Plating & Polishing	42.0401	3471
5.	Comm Eq except Radio & TV	66.0000	48--
6.	Electric Lamps	57.0100	3641
7.	Sheet Metal Work	40.0700	3444
8.	Screw Machine Products	41.0100	345-
9.	Instruments to Measure Electricity	53.0160	3825
10.	Rubber & Plastic Hose & Belting	32.0500	304-
	<u>Aircraft & Missile Engines</u>.		
1.	Aircraft & Missile Engines	60.0200	3724,3764
2.	Misc. Aircraft & Missile Engines	60.0400	3728,3769
3.	Iron & Steel Forgings	37.0300	3462
4.	Iron & Steel Foundries	37.0200	332-
5.	Primary Aluminum	38.0400	3334,2895
6.	Nonferrous Forgings	38.1400	3463
7.	Electrometallurgical Products	37.0102	3313
8.	Misc. Machinery (except electrical)	50.0002	3599
9.	Special Dies & Tools & Machine Tools	47.0300	3544-5
10.	Other Electrical Components	50.0002	3599

Table XIX Cont.

<u>Misc. Aircraft & Missile Eq.</u>.

1.	Misc. Aircraft & Missile Eq.	60.0400	3728,3769
2.	Radio & TV Communications Eq.	56.0400	3662
3.	Aircraft & Missile Engines	60.0200	3724,3764
4.	Semiconductors & Related Devices	57.0200	3674
5.	Aluminum Rolling & Drawing	38.0800	3353-5
6.	Electometallurgical Products	37.0102	3313
7.	Other Electronic Components	57.0300	3675-9
8.	Aircraft	60.0100	3721
9.	Misc. Machinery, except electrical	50.0002	3599
10.	Nonferrous Forgins	38.1400	3463

Reviewing Table XIX reveals an interesting fact about the Space sector--each of its industries is very dependent on their representative commodity and the commodities associated with other Space sector industries. For example, the top three commodities purchased by both the Guided Missile & Spacecraft industry and the Misc. Aircraft & Missile industry are guided missiles, spacecrafts, their components, and misc. missile equipment. The Aircraft & Missile Engine industry is slightly less dependent on the Space sector with its top two commodities falling into this catagory. The only deviation from this trend is the Communication Equipment industry. Only one of its top three commodities purchased is associated with Space sector products. In fact, only one of its top ten classifies. Nevertheless, this deviation make sense. As pointed out earlier, spacecraft and launchers are very complicated and

depend heavily on electronic parts and systems. Virtually every firm in the industry has subcontracting relationships with each other. Bigelow, in an earlier study, produced an interaction matrix that indicated this excessive subcontracting relationship between major spacecraft producers. The matrix revealed, on the average, over a 50 percent interaction between the top twelve firms (8:78-79). on the other hand, the Communications Equipment industry supplies more of the building blocks for the other three Space sector industries and depends more on raw materials for its production. In fact, in 1982 raw materials accounted for over 77 percent of the cost of materials for electronic components and assembled electronic subsystems. This compares with a total cost of raw materials of the Spacecraft industry of less than 2 percent (8:77).

Dependent Industries

Identifying what commodities the Space sector uses is only half the story in determining the space sector's interindustry dependencies. To complete the picture, the industries that are responsible for manufacturing the commodities listed in Appendix E, must be identified. These are the industries that would be required to increase their production during a surge in space related products. To identify these industries, major producers of each commodity were obtained from the Make of Commodities by Industry Input-Output table. For the purposes of this study, a major

producer is any industry that manufactures at least two percent of the total dollar value of a specific commodity.

To identify these industries, a collection of information was compiled from the Make of Commodities by Industries tables and is displayed in Appendix F. Specifically, Appendix F identifies the critical commodity, the total dollar value the commodity's production, the two percent cutoff value to identify major producers, and all the major producers and their dollar value of the critical commodities they produced. (All dollar figures are in 1977 dollars.) In all cases, the major producer of each commodity was its coresponding industry. The number of major producers for any commodity ranged from one to five. In most cases, the dollar value of all industries listed producing the commodity was less than the total value of the commodity produced. This is because there are other industries producing the commodity that did not classify as major producers. Nevertheless, in almost all cases, the major producers listed accounted for over 90 percent of the commodity's total production value. The worst case was the production of Nonferrous Forgings--only 83 percent was manufactured by the major producers. In all, there were 118 industries producing the 92 commodities classified as critical to support a surge in the Space sector. A complete list of all the industries by name is provided in Appendix G.

Of the 118 industries, the Crude Petroleum & Natural Gas; Nonmetallic Mineral Services; and Chemical Mineral Mining are not classified as manufacturing industries. Instead, by BEA definition they fall under the heading of mining industries (14). Thus, for the purposes of this study, these industries will be disreguarded from further analysis.

Conclusion

Through the use of input-output analysis, this chapter demonstrated a systematic methodology to identify all the major commodities used by the Space sector, and the industries that manufacture them. Of the 537 commodiites reported by the BEA, 92 manufactured commodiites were identifed as necessary to support the Space sector. Overall, each Space sector industry was very dependent on its own commodity and the commodities associated with the other three Space sector industries. (This further backed the belief of previous studies that Space sector is composed of highly interactive industries.) The only exception to this is in the Communication Equipment industry. This author believes it is accounted for by the nature of the product. The Communication Equipment industry, unlike the other Space sector industries, produces more basic components--the building blocks of space systems--and thus depends more on raw materials. Finally, a total of 115 industries were identified as major manufacturing producers

of the 92 critical commodities. Exactly how much each industry must produce to meet a surge, and an analysis of their capacity to respond to that demand, is addressed in the next chapter.

VI. Measuring Vulnerability

Chapter V utilized the fundamentals of Input-Output analysis to identify the interindustry dependencies between the Space sector and the manufacturing industries of the economy. This chapter extends that analysis and evaluates the capacity of those industries to respond to a surge demand in space products. Towards this purpose, this chapter first determines the amount of production required by each industry identified in Chapter V to support a surge demand. Next it examines the need to differentiate between the magnitude of dependency and the degree of vulnerability an industry faces in increasing its production. Finally, it utilizes capacity rates to gauge and identify any potential vulnerability in meeting a surge demand.

Measuring Dependency

The first step in determining if the industries identified in Chapter V can respond to a surge demand is to calculate how much each industry must produce to meet an increase in space product demand. As presented in Chapter IV, Input-Output analysis provides a unique solution to measuring the total dependency--both direct and indirect demand--one industry has for another. The total output required of all industries, to accommodate a given final consumption, is the product of the economy's total consumption demand and the inverse matrix for that economic system. Equation (7) displays the vector notation developed

in Chapter IV:

$$X = (I - A)^{-1} * (C) \tag{7}$$

where X represents the vector of outputs required, C represents the vector of final consumption, and $(I-A)^{-1}$ is the inverse matrix. The benefits of this approach is in what the inverse matrix represents--a matrix of coefficients, b_{ij}, that solve the series of equations of output, X, as a linear combination of consumption C:

$$X_i = b_{ij} * C_i \tag{8}$$

Equation (8) lets us evaluate how changes in final consumption effect each industry's total output. Thus, to determine the production required to meet a surge demand by all 115 industries identified in Chapter V, one need only solve equation (8) for all 115 industries. (Remember, of the 118 identified in Chapter V and listed in Appendix G, three industries--the Crude Petroleum & Natural Gas; Nonmetallic Mineral Services; and Chemical Mineral Mining are not classified as manufacturing industries, and were dropped from further analysis.)

The problem with this approach is trying to solve large Inverse Matrices. The procedure itself is straight forward, and is simply the Adjoint of (I-A) divided by the determinant of (I-A), as shown below:

$$(I - A)^{-1} = \frac{\text{Adjoint}\,(I - A)}{|I - A|} \qquad (9)$$

where the Adjoint of (I-A) is the transpose of the Cofactor Matrix, and $|I-A|$ is the determinant of (I-A). (The Cofactor Matrix is a collection of Minors for each element. A Minor is the determinant of the (N-1) x (N-1) submatrix.) However, an Inverse Matrix, to truly represent the Space sector as identified in this study, would require a N x N matrix where N equals at least 100. Thus, the Cofactor Matrix would be a collection of 10,000 Minors, where each Minor was a (N-1) x (N-1) matrix itself. If that was not enough, the determinant of each Minor is evaluated by the equation below:

$$|A| = \det A = (-1)\, A_{1k}\, A_{2k}\, .\, .\, .\, A_{nk} \qquad (10)$$

and entails forming all products, N! in number, of one element A from each row and column (13; 54; 65). As one can see, the calculations to determine the Inverse Matrix are indeed tedious. One way around this problem is to utilize the BEA's Industry-by-Commodity Total Requirements Table. The table is a collection of Input-Output coefficients already solved for the U.S. economy. The values measure the required output, in dollars, of each industry necessary to accommodate the delivery of one dollar's worth of some commodity (15:V). For example, the

Input-Output coefficient for the Communication Equipment industry--spacecraft commodity is .15846. This means that for every dollar of spacecraft delivered in final demand the Communications Equipment industry has a total requirement, both direct and indirect, of 15.85 cents. An interesting figure is the coefficient for the Space Propulsion industry--space propulsion commodity. The coefficient equals 1.03646, and tells us that for each dollar of space propulsion equipment delivered as final demand the Space Propulsion industry has a requirement greater than $1.00. At first this is hard to conceptualize; however, one must remember that in addition to supporting itself in the production of space propulsion units, the industry must also support/supply other industries that support the production of space production units. The major problem with using these coefficients, as identified earlier in this study, is that the latest table produced by the BEA reflects the 1977 economy. Thus, for the purposes of this study, one must assume that technological relationships that exist between industries remains stable over time. A complete list of the coefficients for each of the Space sector's industries is contained in Appendix H.

If equation (8) is divided by each industry's total output, as shown below in equation (11), the percentage increase in total annual output required by each industry to support a surge increase can be calculated (47:26). Total

output for each industry can be obtained in Department of Commerce publications. The most complete information this author could find for all 115 industries was for 1982. A complete listing for each industry's output is contained in Appendix I.

$$\% \text{ Prod Increase} = \frac{(\text{I-O Coefficient}) \times (\text{Surge Increase})}{(\text{Total Output of Supplier Sector})} \qquad (11)$$

With both the Input-Output coefficient and total output of each industry determined, the next step in calculating the amount of production require by each industry is to identify the magnitude of the surge demand; specifically, how much additional space products are required over a given period of time. For purposes of authenticity and the enhanced quality of this manuscript, it would be beneficial to know exactly what increase in spacecraft, launches, and ground equipment the U.S. might face in the near, or distant future. However, these exact demands are not known and are worthy of an entire investigation themselves. Even requirements for SDI, the most probable source of a surge demand, are not defined in terms of actual systems that need to be built. Thus, for the purposes of this paper, a more general approach was taken. The surge demand for this study is assumed to be a 100 percent increase in total government expenditures for each industry in the Space sector--values for the four industries is contained in Table XX below.

This information, is taken from the 1982 Shipments to Federal Government Agencies, produced by the U.S. Department of Commerce. Like the total output of each industry, this information is based on the 1982 total value of shipments and receipts, and represents the most current and complete information available at this time.

Table XX

Surge Demand By Space Sector Industry
Based on Government Shipments

Industry	Surge Demand *
Guided Missiles & Space Vehicles	$9315.0
Radio & Comm Equipment	$3368.4 **
Space Propulsion Equipment	$2081.4
Misc. Space Vehicle Equip.	$1862.1

* Figures in millions of 1982 dollars
** Based on earlier analysis (see Chapter III), this figure is derived by adjusting government purchases of communications equipment to 20 percent of its total value.

Source: 23

The choice of the 100 percent increase to represent the surge demand is merely an estimate, and may be either an overstatement or an understatement of actual surge demand. Nevertheless, it forms a foundation upon which this study may build. Due to the flexibility of Input-Output analysis

this number can be easily modified/changed to reflect updated information or various scenarios that any decision maker wishes to evaluate. In addition, as Miller points out, the choice of a 100 percent increase in demand has a nice side benefit--it represents the percentage of the supplier industry's annual total output required to support the Space sector's annual delivery of goods to the DoD (47:27). For example, say a five percent increase is calculated with Equation (11) for the Carbon & Graphite Materials industry. What that means, in addition to having to increase its production five percent to meet a surge demand of 100 percent, is that currently five percent of the Carbon & Graphite Materials industry's total output goes to supporting the government's demand of space products.

Table XXI lists the results to Equation (11) for the 15 industries requiring the largest percentage increase due to the 100 percent increase in final demand of space products by the DoD. In addition to the total percentage increase demanded, the table identifies each industry's requirements by product. The overall results are pretty diversified. The largest percentage increase in production falls on the Space sector industries themselves. The most significant results is the 115.2 percent increase required by the Space Propulsion Equipment industry. Thus, for the industry to double its production it must actually produce more than twice its current production. The Space

Propulsion Equipment industry is not the only industry that must increase production considerably to meet a 100 percent surge demand. Table XXI points out that both the Misc. Space Equipment and the Guided Missile and Space Vehicle industries require large percentage increases--95.22 and 87.84 respectively. Right in the middle of the range of results is the Communications Equipment industry with a required increase of 45.24 percent. This lower figure represents, in part, the greater diversity of the products the industry produces. At the lower end of the percentage scale is all the other 111 industries identified in Chapter V. Their results range from as high as 5.14 percent to less than .01 percent.

Table XXI

Required Percent Increase By Industry To Support
A 100 Percent DoD Surge Of Space Products

	Space Sector Products Req.				Total Req
Industry	13.01	56.04	60.02	60.04	
Missile Engines	11.1	.4	98.0	6.0	115.5
Misc. Missile Equip.	26.8	1.0	5.9	61.5	95.2
Complete Guided Missile & Spacecraft	86.3	.6	.2	.7	87.8
Radio & Comm Equip.	11.4	32.8	.2	.8	45.2
Fabricated Rubber	1.7	1.0	1.6	.8	5.1
Carbon & Graphite	4.4	.3	.2	.1	5.0
Misc. Electric Comp.	1.7	3.0	.1	.1	4.9
Non-Ferrous Forgings	1.1	.2	2.5	1.1	4.9
Electron Tubes	1.7	2.7	.2	.2	4.8
Misc. Non-Ferrous Casting	1.2	.3	2.2	.6	4.3
Plating & Polishing	1.5	2.0	.1	.4	4.0
Misc. Non-Ferrous Rolling	1.6	1.0	.7	.5	3.8
Iron & Steel Forgings	.6	.1	2.4	.5	3.6
Aircraft	.9	.1	.2	2.3	3.5
Semi-Conductors	.9	1.8	.1	.3	3.0

The problem with this approach is that the percentage figures derived above are probably less than the actual increase required. The reason for this is the broad

generalization used for each industry. Not every industry is as specialized as the Spacecraft or Missile Engine industry. Industries, like the Radio & Communications Equipment industry, have far more products listed under them than those that pertain to space products. A perfect example is the Optical Instruments & Lenses industry. This industry supplies various products to the Space sector, both directly and indirectly--products like special satellite lenses. However, the industry also includes firms that produce products like everyday eye glasses. Thus, the calculation of 1.18 percent is based on a total production figure which is too big since not every firm listed in the industry can produce the equipment required by the Space sector. Instead, if only those firms in the industry which could actually produce the equipment that is used by the Space sector where used, the denominator in equation (11) would be smaller and the percentage increase larger.

Model Flexibility. Input-output analysis, as mentioned earlier, offers considerable flexibility. One need not just evaluate a 100 percent increase on all space products. It is possible to vary the demands of each product separately. One interesting question, along these lines, might be what impact would more autonomous spacecraft have on the economy's infrastructure. By more autonomous spacecraft we mean those that do more thinking for themselves, and do not rely on ground support as much. A surge demand of this nature might be best represented by a 100 percent increase

in all space products except the ground equipment, or maybe a 200 percent increase in space equipment with only a 100 percent increase in ground equipment. Table XXII shows the results of these two other scenarios along with this study's original one. The numbers in the parentheses represent the total requirements ranking by percentage increases.

In all three cases, the same three industries required the largest percentage of increase. This is really no surprise since the demand for their product increase relative to the demand for ground equipment. Nevertheless, the table reveals some interesting facts. First, without even a demand for ground equipment, the demand for communications equipment increased 12.47 percent in the second scenario. This points out what was reported earlier in this study; the fact that spacecraft and launchers are heavily dependent on electric components. The second major point is that not all the 115 industries are effected equally by shifts in the composition of space products. The reduced demand for ground equipment has an impact on the economy that can be seen by the relative shift of the various industry rankings. Those industries that support the production of ground equipment more than others--the Misc. Electric Component, Semi-Conductor, Electric Tube, and Misc. Non Metalic Mineral industries--all dropped considerably in the overall ranking.

Table XXII

Total Percentage Increase In Production By Industry Required Due To Surge Scenarios

Industry	Surge I	Surge II	Surge III
Missile Engines	115.52 (1)	115.21 (1)	230.63 (1)
Misc. Missile Equip.	95.22 (2)	94.11 (2)	189.49 (2)
Complete Guided Missile & Spacecraft	87.84 (3)	87.20 (3)	175.04 (3)
Radio & Comm Equip.	45.24 (4)	12.47 (4)	57.72 (4)
Fabricated Rubber	5.14 (5)	4.12 (7)	9.27 (7)
Carbon & Graphite	4.99 (6)	4.68 (6)	9.67 (5)
Misc. Electric Comp.	4.90 (7)	2.10 (14)	7.01 (11)
Non-Ferrous Forgings	4.86 (8)	4.67 (5)	9.53 (6)
Electron Tubes	4.84 (9)	1.81 (19)	6.65 (12)
Misc. Non-Ferrous Casting	4.27 (10)	3.94 (8)	8.22 (8)
Plating & Polishing	4.00 (11)	2.01 (16)	6.02 (14)
Misc. Non-Ferrous Rolling	3.78 (12)	2.75 (9)	6.54 (13)
Iron & Steel Forgings	3.64 (13)	3.51 (10)	7.15 (9)
Aircraft	3.58 (14)	3.49 (11)	7.07 (10)
Semi-Conductors	3.06 (15)	1.25 (25)	4.31 (20)

Surge I scenario--100 percent increase in all space products.

Surge II--100 percent increase in all space products except ground equipment, they do not increase.

Surge III--200 percent increase in all space products except ground equipment, they increase only 100 percent.

Vulnerability Versus Dependency

Fundamental to understanding the surge capability of the economy is an appreciation of the contrast between the perceived importance placed on just the magnitude of interindustry dependency and the reality of an industry's capacity to increase its demand. Dependency, by itself, is a readily identifiable concept--an industry is dependent on others when it relies on those others for inputs. Overall, this study identified 115 industries the Space sector is dependent on. It is possible to get a rough gauge of the Space sector's dependency on these industries by comparing the information contained in Table XXI However, identifying the magnitude of dependency does not necessarily determine if an industry can actually increase its production to respond to the surge. Instead, one must compare each industry's _required_ production increase with its _ability_ to increase its production. For example, lets say the Guided Missile industry is heavily dependent on the Communication Equipment industry and only slightly dependent on the Tool and Die industry. Thus, a large increase in the demand for guided missiles will cause a large increase in the amount of communication equipment and only a moderate increase in the demand for special tools and dies. Yet, ideally, if the Communication industry has considerable excess capacity than a large increase in demand from the Guided Missile industry will cause little problems. On the other hand, if the Tool and Die industry has very little excess capacity even a

moderate increase in demand might cause a problem that could result in a delay, or, possibly, the shut down a guided missile production line. Thus, the ability of an industry to respond to an increase in demand depends not just on the magnitude of the demand, but also on the capacity of the industry to expand and accommodate that increase in demand.

Capacity Utilization. There are many factors which influence an industry's ability to respond to a surge in demand--access to critical materials, labor, the environment of government regulations, and even managements desires to increase production are just a few. However, many of these factors are hard to quantitatively analyze. One factor, that lends itself to measurement, and the one used in this study, is industry capacity utilization. Miller defines capacity utilization as "the level of operation at which an industry operates relative to the level that it could achieve within the framework of a realistic work pattern" (47:34). The Department of Commerce identifies two distinct capacity utilization rates: preferred rate and practical rate (25:V). The preferred utilization rate is simply a ratio of the actual to preferred level of production. The preferred level of production is where an industry wants to produce and not exceed due to cost considerations.. This level is associated with profit maximization, and is defined in Price Theory as the point where marginal revenue equals marginal cost. The second utilization rate, practical rate,

is the ratio of actual to <u>practical</u> level of production. The practical level of production is defined as the "greatest output the plant [industry] could achieve within the framework of realistic work pattern" (25:V). In meeting this rate industries assume an availability of inputs, such as labor and materials, sufficient to utilize their equipment on hand.

A complete list of both preferred and practical utilization rates for 1982 was obtained from the U.S. Department of Commerce's <u>Survey of Plant Capacity</u>, and is contained in Appendix K. However, since the information is broken out by four digit (industry) SIC code, there is not a 100 percent match-up with this study's use of BEA industrial classification. As described above, there are some cases where the BEA calls for the grouping of more than one SIC industry in its classification scheme. In those cases, this study took a "worst case scenario", and represented the BEA industry with the highest capacity utilization rate for the group of SIC industries. In addition, there where some SIC industries that did not list rates for 1982 due to survey problems. In those cases rates from the next closest year where used.

Overall, preferred rates ranged from 33 to 95 percent, while practical rates varied about the same with just a little lower mean and a range from 30 to 88 percent. In almost all cases the practical rate is less than the preferred rate. In the cases where the two rates are equal

it is more than likely due to those industries working under other than a price maximization assumption. Instead, they might be responding to desires to maximize revenue--many managerial incentives are tied directly to sales rather than profit. Thus, their ideal of preferred and practical are probably the same since they want to produce as much as they can all the time.

Based on capacity utilization, it is possible to derive the percentage each industry is capable of increasing its production--both preferred and practical. This is simply the unused capacity divided by the current capacity (see equation 12 below). Appendix L is a complete list of each industry's ability to increase based on their preferred and practical utilization rates. Notice, in agreement with what was said earlier, in almost all cases the ability for an industry to increase its production base is larger for practical rates rather than preferred rates. Figures vary for the preferred rates as much as 4.1 to 203 percent. As would be expected, the range of expansion is somewhat more for the practical rates with a low of 4.1 and a high of 233.3 percent.

$$PI = 100 * (100 - CU) / CU \qquad (12)$$

Where:

PI = percentage of increase in production available

CU = capacity utilization

Exactly which ratio is more representative of an industry's ability to expand is hard to say. Studies of this nature in the past have dwelled on just the preferred utilization rate (37; 47). At first glance that would seem likely, since a surge demand deals with just an industry's ability to accelerate production in support of events short of war or national emergencies. There appears to be no reason why a firm would produce beyond their maximum profit level--that is their preferred level of capacity. Nevertheless, the overall Defense sector, which the Space sector is part of due to its large dependency on government contracts, does not always act according to the laws of price theory. Demand for defense products is highly cyclical and do not always follow long-range plans, but instead, political environments. Many industries feel that when the demand comes they have to grab on to as much as they can, both for the sake of the present and the future. Present, because once a defense contract is let it is almost set in concrete with very little chance of cancellation. Future, because of possible follow-on contracts for both system modifications and additional buys. In addition, some argue there is a sense of comradery between the government and many of the major contractors. A sense of loyalty to help each other out when the going gets tough (30:485). What ever the case, there is no clear cut answer as to which utilization rate is more effective. Instead, both rates

should be used to provide a more flexible approach with a better range of estimates to gauge vulnerability from.

It is necessary to point out that capacity utilization rates are based on an average of the entire industry; industries which encompass more than just specific space related firms. Like the figures used for total output in Equation (11), it is possible that the capacity utilization rates are not a true representation, and may either overstate or understate capacity rates for specific products. For example, part of the propulsion system for the space shuttle's orbiter are cryogenic tanks. These tanks are used to hold cryogenic propellent--a liquified gas at low temperatures, such as liquid oxygen (-147 C) or liquid hydrogen (-253 C) (62:147). Capacity to increase their production would be reflected in the capacity utilization rates of the Missile Engines, and/or Misc. Missile Equipment industries. However, Beech Aircraft is the only company that made them--Beech Aircraft is no longer in business (49:32). Thus, even if there was considerable excess capacity in those industries, if the primary manufacture, such as Beech Aircraft, did not have the excess capacity chances are there would be considerable delay in getting the product built. It is the contention of this study that some other firm in those industries would pick up where Beech Aircraft left off. However, just looking at capacity utilization rates for an entire industry could be misleading and is less useful in realistically evaluating

the vulnerability in each industry. Nevertheless, do to the scope of this study and the imformational limitations, capacity utilization rates by entire industries will be used as given.

Potential Vulnerabilities

The benefit of converting each industry's capacity utilization rate to percentage figures is the common ground obtained with this chapter's earlier results of percentage increase production requirements. It is now possible to divide each industry's required increase percentage by its unused capacity percentage to provide a ratio to measure of each industry's vulnerability to surge. Ratio values less than one indicates an industry has enough excess capacity to meet production increases, while values greater than one indicate the industry does not have enough excess capacity. (Note, if these ratios are multiplied by 100 they represent the percentage of excess capacity needed to meet the given surge demand.)

It must be stressed that this ratio is just a rough estimate, and can not be used to evaluate an industry's ability to increase production in a vacuum. First, the ratio is based entirely on capacity utilization. As mentioned earlier, it fails to take into account the availability of materials and labor. Second, it says nothing about an industry's desire to shift its excess capacity to the production of these goods. Keeping in mind

the limitations mentioned above, it is still beneficial to evaluate surge ratios for each industry. Table XXIII list the ten most vulnerable industries based on calculated surge ratios. A complete list of surge ratios for each industry is contained in Appendix M.

Table XXIII

10 Most Vulnerable Industries In Support
Of A 100 Percent Increase In Space Products

Industry	Surge Ratio Preferred	Surge Ratio Practical
Missile Engines	3.465	2.053
Guided Missiles & Spacecraft	2.374	1.495
Misc. Missile Equip.	1.553	1.117
Radio & Comm. Equip.	1.514	.918
Metal & Heat Treating	.410	.410
Electronic Tubes	.192	.137
Misc. Electronic Components	.139	.095
Semi-conductors & Related Devices	.102	.072
Primary Lead	.081	.068
Fabricated Rubber Products	.077	.062

In addition to measuring the effect an overall increase would have on the economy, it is possible to identify the surge ratios for each industry supporting the production of

each specific space related product: spacecraft, ground equipment, propulsion units, and miscellaneous equipment seperately. Table XXIV list the 6 most vulnerable industries for each space product. Unlike the ratios identified in Table XXIII, Table XXIIV it breaks out the effect of each product on the economy.

Table XXIV

Six Most Vulnerable Industries Supporting
A 100 Percent Increase In Final Demand By Space Product

Product	Surge Ratio*
Guided Missiles & Spacecraft	
Guided Missiles & Spacecraft Indus.	2.33
Misc. Missile Equipment Indus.	.44
Radio & Comm Equipment Indus.	.38
Missile Engines Indus.	.33
Metal & Heat Treating Indus.	.18
Primary Lead Indus.	.03
Radio & Communication Equip	
Radio & Comm. Equipment Indus.	1.09
Electronic Tubes Indus.	.12
Misc. Electronic Equip. Indus.	.07
Semi-conductor Indus.	.06
Metal & Heat Treating Indus.	.05
Primary Lead Indus.	.02
Missile Engines	
Missile Engines Indus.	2.93
Misc. Missile Equip. Indus.	.09
Metal & Heating Indus.	.09
Misc. Nonferrous Casting	.02
Nonferrous Forgings Indus.	.02
Fabricated Rubber Products	.02
Misc. Missile Equipment	
Misc. Missile Equip. Indus.	1.00
Missile Engine Indus.	.17
Metal & Heat Treating	.08
Aircraft Indus.	.02
Electronic Tubes	.02
Nonferrous Forgings	.01

A significant result identified in both tables is the vulnerability the Space sector faces itself in trying to meet an increase demand in space products from the government. All four industries had less excess capacity than necessary in meeting increased DoD obligations for a surge in all space products and, in addition, for just their product. The largest vulnerability for the production of all space products is in the Missile Engine industry. Its preferred surge ratio of 2.93, in Table XXIV, reveals that for it to meet a 100 percent surge in just missile engines it needs almost three times its current excess capacity. In addition, its preferred surge ratio of 3.465, in Table XXIII indicates that it requires an additional 54 percent excess capacity to support the increase production of other space products. The Guided Missile and Spacecraft industry is the next most vulnerable industry. Its preferred surge ratio of 2.33, in Table XXIV, reveals that, like the Missile Engine industry, it does not have enough excess capacity to support a 100 percent increase in just spacecraft. However, unlike the Missile Engine industry, the Guided Missile and Spacecraft industry needs only 4.5 percent excess capacity to support the production of all other space products. The remaining two industries in the Space sector--Misc. Missile Equipment and Radio & Communication Equipment--are very similar in their results. Both could just about support the increase in their own products; however, both would require an additional 50 percent excess capacity to support a surge

in all space products.

The most significant findings are the results for the practical surge ratios in Table XXIII. Of these, three out of the four Space sector industries have ratios greater than one. This means that even if those industries worked to maximum capacity, assuming they could get all the necessary inputs, they still would not be able to meet the demand in this study's scenario. Of the one Space sector industry that would have enough excess capacity, the Radio & Communications Equipment industry, it is questionable if all of it facilities could, and possibly would be used to accommodate the surge in demand.

In addition to the vulnerability the Space sector faces itself in meeting a surge demand, Table XXIII list the six most vulnerable supply industries. Based on preferred utilization, four industries would need at least 10 percent of their available excess capacity to satisfy a 100 percent increase in DoD space products; while analysis of practical utilization reveals only two. The Metal & Heat Treating industry appears the most vulnerable supply sector, and needs to utilize 41 percent of it excess capacity to accommodate a surge in all space products. In addition, Table XXIV, identifies the Metal & Heat Treating industry as a potentially vulnerable industry in support of each of the separate space products. Yet, Appendix J reveals that this industry requires only a 1.71 percent total increase in

production to support a surge in all space products. The reason for the large vulnerability ratio is the lack of excess capacity. The reported 1982 capacity rates was 96 percent for both the practical and preferred. This indicates that the industry has little room--only 4 percent--to increase its production. The use of such a high capacity utilization rate is questionable, since in 1983 it dropped to 66 percent.

Like the Metal & Heat Treating industry, the next three vulnerable supply industries--Electronic Tubes, Misc. Electronic Components, and Semi-conductors & Related Devices-- required a considerable amount, at least 10 percent, of their excess capacity to support a DoD increase in the demand for space products. Unlike the Metal & Heating industry, their capacity utilization rates are more in tune with the overall American averages--74 percent in 1984, and 71 percent in 1983--and have not experienced any extreme fluctuations. Thus, it seems realistic to assume that these industries, like those whose surge ratios are even smaller have considerable excess capacity to support a surge in space products. (It is interesting to note that the Space sector would rely at all on the electronic tubes in this age of micro-circuitry. Nevertheless, it is necessary to remember that the input-output coefficients used in this study were from 1977--the latest available. Based on these results, it is necessary to question the assumption that the technological relationships the input-

output coefficients depict do not change too much over time.)

Conclusion

The purpose of this chapter was to utilize the fundamentals of Input-Output analysis to evaluate the capacity of the manufacturing industries in the economy to support a surge demand in space products. The first section of this chapter dealt with determining the amount of production required by all 115 supporting manufacturing industries identified in Chapter V. Towards this end, input-output coefficients, derived by the BEA, were used in conjunction with a staged surge scenario to determine the required percent increase necessary for each industry. As expected, the majority of increase reported was in the Space sector itself. Of the other industries supplying the Space sector, very few required considerable increases. In fact, only 12 had increases greater than 3 percent, with the largest being 5.1 percent.

The next section of this chapter was devoted to differentiating between the magnitude of dependency and the degree of vulnerability an industry faces in increasing its production. Once an understanding for this was established, capacity utilization rates were used to determine the amount of excess capacity available in each industry. These results, combined with the results of increase production determined earlier, were used to develop a surge ratio to

provide a rough gauge of industrial vulnerability. Results indicated the only real vulnerability that existed was in the Space sector itself. Each of the Space sector industries were unable to accommodate a 100 percent increase in space products. All of the 113 other manufacturing industries studied appeared to have ample excess capacity to support a surge in space products.

Throughout this chapter's analysis, efforts were taken to identify those areas in the methodology which this author felt were somewhat lacking; specifically, the percentage of production required by each industry, and the capacity utilization rates. Both areas failed to account for the technological advantage/specialty some firms have over others in an industry; thus, estimates of percentage production required and capacity utilization rates were probalbly too low.

VI. Conclusions and Recommendations

Conclusions

The parametric model developed to represent the surge demand in space products provides an accurate method of predicting interindustry dependencies and relative surge capacity as a function of production demand increases and capacity utilization rates. The generality incorporated into the model enables various surge scenarios to be evaluated by simple modification of the required increase production equation and its associated parameters.

The lack of precise data has prevented this analysis from conclusively identifying those industries, or portions of industries, that might prove vulnerable to a surge demand in space products.

1. The most vulnerable industries of those examined are the ones comprising the Space sector itself. All four industries had less excess capacity than necessary to meet the increase demand set forth in this study's scenario. The most significant of the four is the Missile Engine industry which had the largest percentage increase in total production requirements, a total production requirement greater than one-for-one for space products, and a considerable lack of excess capacity to meet any new demands.
2. Of the four Space sector industries, the Communication Equipment industry required the least

increase in total production but due to lack of excess capacity still could not meet this study's surge scenario.

3. An increase in plant capacity, from preferred to practical, produces a significant reduction in the surge ratio in all Space sector industries; however, even with utilizing plants to their utmost capacity these industries still lack the necessary production capability to meet this study's surge scenario.

4. The Metal & Heat Treating industry is identified as the most potentially vulnerable industry in support of each of the Space sector industries; however, its vulnerability is suspect due to its excessive fluctuating capacity rates.

Recommendations

The following recommendations are proposed for further study:

1. Further refine this study's definition of the Space sector down to the level of the firm to provide a more current and precise statistical base for further quantitative analysis.

2. Evaluate the definition of each supporting industry, much in the same way this study evaluated the Communication Equipment industry, to provide a clearer understanding of the magnitude of interaction between each industry and the Space sector.

3. Measure the stability of the input-output coefficients over time for both the Space sector and its supporting industries. If there is a great deal of change this will provide evidence to refute the assumption that interindustry dependencies stay constant, and require that further studies utilize a more dynamic approach to the problem of industrial planning.

4. If current input-output coefficients are considerably constant then utilize the most current Input-Output Tables (when available), and repeat the investigation of commodity/industry dependency and measure each industry's increase production requirements.

APPENDIX A
LIST OF SHUTTLE SUBCONTRACTORS
AND THEIR RESPECTIVE PRODUCT

Company	Product
Aerojet Liquid Rocket Company	Orbiter maneuvering systems engines
AiReasearch Manufactureing	Air data transducer assembly and computer; safety valve; solenoid value
Albany International Company	Nomex felt (for the thermal protection system
Ball Aerospace System Division	Star tracker
Bendix Corporation	Airspeed altimeter; vertical velocity indicator; surface position indicator
B.F. Goodrich Company	Main & nose landing-gear wheel and main landing-gear brake assembly
Boeing Aerospace Company	Carrier aircraft modification
CCI Corporation	Reaction control thrusters
Conrac Corporation	Engine interface unit
Corning Glass Works	Windows, windshield and side hatch; glass-ceramic retainers
Cutler-Hammer	Microwave scanning-beam landing-system navigation
Fairchild Republic	Vertical Tail
General Dynamics Corporation	Mid Fuselage
Grumman Aerospace	Shuttle wings
Honeywell	Flight-control system displays and controls
Hughes Aircraft	Ku-bank radar communication system

Hydraulic Research Textron	Servo actuator elevon-electro command hydraulics; fourway hydraulic system flow control pressure valve
IBM	Mass-memory and multifunction cathode-ray-tube display subsytem; general purpose computer and input-output processor
Instrument System Corporation	Audio distribution system
Lear Siegler	Attitude direction indicator
Lockheed-California	Static and fatigue testing of orbiter structure
Lockheed Missiles and Space	High and low temperature reusable surface insulation
Martin Matietta Corporation	External tank
McDonnell Douglas Corporation	Aft propulsion system
Menassco	Main and nose landing-gear shock struts and brace assembly
Northrop Corporation	Rate gyro assembly
Rockwell International	Space shuttle main engine; orbiter system intergration; cargo-bay doors
Spar Aerospace	Remote manipulator system
Sperry-Rand Corporation	Automatic landing; multiplexer-demultiplexer
Sundstrand Corporation	Auxiliary power unit; rudder-brake actuation unit; Actuation unit hydrogen recirculation pump assembly
Thiokol Corporation	Solid rocket booster motors

TRW	S-band payload interregator; S-band network equipment; network signal processor; payload signal processor
United Tech. Corporation	Solid rocket booster seperation motors; propulsion for inertial upper stage; atmospheric revitalization subsystem, freon coolant loop and flesh evaporator system; hydraulic thermal control unit; shuttle spacesuit; fuel-cell powerplant; solid rocket booster assembly
Vought Corporation	Leading-edge structural subsystem and nosecap; reinforced carbon-carbon; cargo-bay door radiator and flow-control assembly system
Westinghouse Electric Corporation	Remote power controller; electrical system inverters master timing unit

APPENDIX B
NON-NEGLIGIBLE COMMODITIES PURCHASED IN SUPPORT OF THE SPACE SECTOR

BEA CODE	COMMODITY
4.0002	Agricultural & Forestry Services
7.0000	Coal Mining
12.0201	Maintenance of Nonfarm Buildings
13.0100	Complete Guided Missiles
13.0500	Small Arms
14.0101	Meat Packing Plants
14.0102	Prepared Meats
14.0103	Poultry Dressing Plants
14.2103	Wines & Brandy
14.2104	Distilled Liquor
16.0100	Broadwoven Fabric Mills
16.0200	Narrow Fabric Mills
18.0400	Apparel from Purchased Materials
20.0200	Sawmills & Planing Mills
20.0600	Veneer & Plywood
20.0800	Wood Preserving
20.0901	Wood Pallets & Skids
21.0000	Wood Containers
22.0102	Household Furniture
22.0103	Wood TV & Radio Cabinets
23.0300	Public Building Furniture
24.0400	Envelopes
24.0500	Sanitary Paper Products
24.0701	Paper Coating & Glazing
24.0702	Bags (Except Textile)
24.0703	Die-Cut Paper & Board
24.0705	Stationary Products
24.0706	Converted Paper Products
25.0000	Paperboard Containers & Boxes
26.0200	Periodicals
26.0301	Book Publishing
26.0400	Miscellaneous Publishing
26.0501	Commercial Printing
26.0601	Mainfold Business Forms
26.0602	Blankbooks & Looseleaf Binders
26.0801	Engraving & Plate Printing
27.0100	Inorganic & Organic Chemicals
27.0406	Chemical Preperations
28.0100	Plastic Materials & Resins
28.0200	Synthetic Rubber
30.0000	Paints & Allied Products
30.0101	Petroleum Refining Products
31.0102	Misc. Petroleum Refining Products
32.0100	Tires & Inner Tubes
32.0302	Fabricated Rubber Products

32.0400	Misc. Plastic Products
32.0500	Rubber & Plastic Hose & Belting
34.0301	Leather Gloves & Mittens
34.0302	Luggage
34.0304	Personal Leather Goods
34.0305	Misc. Leather Goods
35.0100	Glass & Glass Products
36.0800	Porcelain Electric Supplies
36.1600	Abrasive Products
36.1700	Asbestos Products
36.1800	Gaskets, Packing & Sealing Devices
36.1900	Minerals, Ground or Treated
36.2200	Misc. Nonmetallic Mineral Products
37.0101	Blast Furnaces & Stell MMills
37.0200	Iron & Steel Foundaries
37.0300	Iron & Steel Forgings
37.0401	Metal & Heat Treating
37.0402	Misc. Primary Metal Products
38.0400	Primary Aluminum
38.0500	Misc. Primary Nonferrous Metals
38.0700	Copper Rolling & Drawing
38.0800	Aluminum Rolling & Drawing
38.0900	Misc. Nonferrous Rolling & Drawing
38.1000	Nonferrous Wire Drawing & Insulating
38.1100	Aluminum Casting
38.1200	Brass, Bronze, & Copper Casting
38.1300	Misc. Nonferrous Casting
38.1400	Nonferrous Forgings
40.0400	Fabricated Structural Metal
40.0700	Sheet Metal Work
40.0902	Prefabricated Metal Buildings
41.0100	Screw Machine Products
41.0203	Misc. Metal Stampings
42.0100	Cutlery
42.0201	Misc. Hand & Edge Tools
42.0202	Crowns & Closures
42.0300	Misc. Hardware
42.0401	Plating & Polishing
42.0402	Metal Coating & Allied Services
42.0500	Misc. Fabricalted Wire Products
42.0800	Pipe, Valves, & Pipe Fittings
42.1000	Metal Foil & Leaf
42.1100	Misc. Fabricated Metal Products
47.0100	Machine Tools, Metal Cutting Types
47.0200	Machine Tools Metal Forming Types
47.0300	Special Dies & Tools
47.0401	Power Driven Hand Tools
47.0403	Misc. Metalworking Machinery
49.0100	Pumps & Compressors
49.0200	Ball & Roller Bearings

49.0500	Power Transmsission Equipment
49.0700	Misc. General Industry Machinery
50.0002	Misc. Machinery (Except Electrical)
51.0101	Electrical Computing Equipment
53.0100	Instruments to Measure Electricity
53.0200	Transformers
53.0400	Motors & Generators
53.0500	Industrial Controls
53.0700	Carbon & Graphite Products
53.0800	Misc. Electrical Industrial Apperatus
55.0100	Electric Lamps
55.0200	Lighting Fixtures & Equipment
55.0300	Wiring Devices
56.0100	Radio & TV Receiving Sets
*56.0400	Radio & Communication Equipment
57.0100	Electron Tubes
57.0200	Semiconductors & Related Devices
57.0300	Misc. Electronic Components
58.0100	Storage Batteries
58.0400	Engine Electrical Equipment
58.0500	Misc. Electrical Equipment
59.0302	Motor Vehicle Parts & Accessories
60.0100	Aircraft
*60.0200	Aircraft & Missile Engines
*60.0400	Misc. Aircraft & Missile Equipment
62.0100	Engineering & Scientific Instuments
62.0200	Mechanical Measuring Devices
62.0500	Surgical Appliances & Supplies
63.0100	Optical Instruments & Lens
63.0200	Ophthalmic Goods
63.0300	Photographic Equipment & Supplies
64.0104	Silverware & Plated Ware
64.0400	Misc. Sporting Goods
64.0501	Pens & Mechanical Pencils
64.0502	Lead Pencils & Art Goods
64.0503	Marking Devices
64.0504	Carbon Paper & Inked Ribbons
64.0800	Brooms & Brushes
64.1200	Misc. Manufacturing Industries
65.0100	Railroads & Related Services
65.0200	Passenger Transportation
65.0300	Motor Freight Transportation
65.0400	Water Transportation
65.0500	Air Transportation
65.0600	Pipe Lines (Except Natural Gas)
65.0702	Arrangement of Passenger Transpo.
66.0000	Communications (Except Radio & TV)
68.0100	Electric Services (Utilities)
68.0200	Gas Production & Distribution
68.0301	Water Supply & Sewerage Systems
68.0302	Sanitary Services & Steam Supply

69.0100	Wholesale Trade
69.0200	Retail Trade
70.0100	Banking
70.0200	Credit Agencies
70.0300	Security & Commodity Brokers
70.0400	Insurance Carriers
71.0200	Real Estate
72.0100	House & Lodging Places
72.0201	Laundry & Cleaning Services
72.0204	Electrical Repair Shops
73.0101	Misc. Repair Shops
73.0102	Services to Dewllings & Buildings
73.0103	Personnel Supply Services
73.0104	Computer & Data Processing Services
73.0105	Management & Consulting Services
73.0106	Detective & Protective Services
73.0107	Equipment Rental & Leasing Services
73.0108	Photofinishing Labs
73.0109	Misc. Business Services
73.0200	Advertising
73.0301	Legal Services
73.0302	Engineering & Surveying Services
73.0303	Accounting & Misc. Services
74.0000	Eating & Drinking Places
75.0001	Automobile Renting & Leasing
75.0002	Automobile Repair Shops & Services
76.0100	Motion Pictures
76.0201	Entertainers (Bands & Theatrical)
76.0203	Commercial Sports (Except Racing)
76.0205	Membership Sports & Recreation Clubs
77.0402	Universities & Proffesional Schools
77.0501	Business/Proffesional Membership Org.
77.0504	Misc. Membership Organizations
77.0600	Job Training & Related Services
78.0100	U.S. Postal Services
79.0300	Misc. State & Local Government Enter.
80.0000	Noncomparable Imports

APPENDIC C
COMMODITIES PRODUCED BY
NON-MANUFACTURED INDUSTRIES

BEA CODE	NON-MANUFACTURED COMMODITIES
4.0002	Agricultural & Forestry Services
7.0000	Coal Minning
12.0201	Maintenance of Nonfarm Buildings
65.0100	Railroads & Related Services
65.0200	Passenger Transportation
65.0300	Motor Freight Transportation
65.0400	Water Transportation
65.0500	Air Transportation
65.0600	Pipe Lines (Except Natural Gas)
65.0702	Arrangement of Passenger Transpo.
66.0000	Communications (Except Radio & TV)
68.0100	Electric Services (Utilities)
68.0200	Gas Production & Distribution
68.0301	Water Supply & Sewerage Systems
68.0302	Sanitary Services & Steam Supply
69.0100	Wholesale Trade
69.0200	Retail Trade
70.0100	Banking
70.0200	Credit Agencies
70.0300	Security & Commodity Brokers
70.0400	Insurance Carriers
71.0200	Real Estate
72.0100	House & Lodging Places
72.0201	Laundry & Cleaning Services
72.0204	Electrical Repair Shops
73.0101	Misc. Repair Shops
73.0102	Services to Dewllings & Buildings
73.0103	Personnel Supply Services
73.0104	Computer & Data Processing Services
73.0105	Management & Consulting Services
73.0106	Detective & Protective Services
73.0107	Equipment Rental & Leasing Services
73.0108	Photofinishing Labs
73.0109	Misc. Business Services
73.0200	Advertising
73.0301	Legal Services
73.0302	Engineering & Surveying Services
73.0303	Accounting & Misc. Services
74.0000	Eating & Drinking Places
75.0001	Automobile Renting & Leasing
75.0002	Automobile Repair Shops & Services
76.0100	Motion Pictures

76.0201	Entertainers (Bands & Theatrical)
76.0203	Commercial Sports (Except Racing)
76.0205	Membership Sports & Recreation Clubs
77.0402	Universities & Proffesional Schools
77.0501	Business/Proffesional Membership Org.
77.0504	Misc. Membership Organizations
77.0600	Job Training & Related Services
78.0100	U.S. Postal Services
79.0300	Misc. State & Local Government Enter.
80.0000	Noncomparable Imports

APPENDIX D
MANUFACTURED COMMODITIES USED
IN THE PHERIPHERAL SUPPORT
OF THE SPACE SECTOR

BEA CODE	PHERIPHERAL SUPPORT COMMODITIES
14.0101	Meat Packing Plants
14.0102	Prepared Meats
14.0103	Poultry Dressing Plants
14.2103	Wines & Brandy
14.2104	Distilled Liquor
16.0100	Broadwoven Fabric Mills
16.0200	Narrow Fabric Mills
18.0400	Apparel from Purchased Materials
20.0200	Sawmills & Planing Mills
20.0600	Veneer & Plywood
20.0800	Wood Preserving
20.0901	Wood Pallets & Skids
21.0000	Wood Containers
22.0102	Household Furniture
22.0103	Wood TV & Radio Cabinets
23.0300	Public Building Furniture
24.0400	Envelopes
24.0500	Sanitary Paper Products
24.0701	Paper Coating & Glazing
24.0702	Bags (Except Textile)
24.0703	Die-Cut Paper & Board
24.0705	Stationary Products
24.0706	Converted Paper Products
25.0000	Paperboard Containers & Boxes
26.0200	Periodicals
26.0301	Book Publishing
26.0400	Miscellaneous Publishing
26.0501	Commercial Printing
26.0601	Mainfold Business Forms
26.0602	Blankbooks & Looseleaf Binders
26.0801	Engraving & Plate Printing
64.0104	Silverware & Plated Ware
64.0400	Misc. Sporting Goods
64.0501	Pens & Mechanical Pencils
64.0502	Lead Pencils & Art Goods
64.0503	Marking Devices
64.0504	Carbon Paper & Inked Ribbons
64.0800	Brooms & Brushes
64.1200	Misc. Manufacturing Industries

APPENDIX E
MANUFACTURED COMMODITIES CRITICAL TO SUPPORT THE SPACE SECTOR

BEA CODE	CRITICAL MANUFACTURED COMMODITIES
*13.0100	Complete Guided Missiles
13.0500	Small Arms
27.0100	Inorganic & Organic Chemicals
27.0406	Chemical Preperations
28.0100	Plastic Materials & Resins
28.0200	Synthetic Rubber
30.0000	Paints & Allied Products
30.0101	Petroleum Refining Products
31.0102	Misc. Petroleum Refining Products
32.0100	Tires & Inner Tubes
32.0302	Fabricated Rubber Products
32.0400	Misc. Plastic Products
32.0500	Rubber & Plastic Hose & Belting
34.0301	Leather Gloves & Mittens
34.0302	Luggage
34.0304	Personal Leather Goods
34.0305	Misc. Leather Goods
35.0100	Glass & Glass Products
36.0800	Porcelain Electric Supplies
36.1600	Abrasive Products
36.1700	Asbestos Products
36.1800	Gaskets, Packing & Sealing Devices
36.1900	Minerals, Ground or Treated
36.2200	Misc. Nonmetallic Mineral Products
37.0101	Blast Furnaces & Stell MMills
37.0200	Iron & Steel Foundaries
37.0300	Iron & Steel Forgings
37.0401	Metal & Heat Treating
37.0402	Misc. Primary Metal Products
38.0400	Primary Aluminum
38.0500	Misc. Primary Nonferrous Metals
38.0700	Copper Rolling & Drawing
38.0800	Aluminum Rolling & Drawing
38.0900	Misc. Nonferrous Rolling & Drawing
38.1000	Nonferrous Wire Drawing & Insulating
38.1100	Aluminum Casting
38.1200	Brass, Bronze, & Copper Casting
38.1300	Misc. Nonferrous Casting
38.1400	Nonferrous Forgings
40.0400	Fabricated Structural Metal
40.0700	Sheet Metal Work
40.0902	Prefabricated Metal Buildings

41.0100	Screw Machine Products
41.0203	Misc. Metal Stampings
42.0100	Cutlery
42.0201	Misc. Hand & Edge Tools
42.0202	Crowns & Closures
42.0300	Misc. Hardware
42.0401	Plating & Polishing
42.0402	Metal Coating & Allied Services
42.0500	Misc. Fabricalted Wire Products
42.0800	Pipe, Valves, & Pipe Fittings
42.1000	Metal Foil & Leaf
42.1100	Misc. Fabricated Metal Products
47.0100	Machine Tools, Metal Cutting Types
47.0200	Machine Tools Metal Forming Types
47.0300	Special Dies & Tools
47.0401	Power Driven Hand Tools
47.0403	Misc. Metalworking Machinery
49.0100	Pumps & Compressors
49.0200	Ball & Roller Bearings
49.0500	Power Transmsission Equipment
49.0700	Misc. General Industry Machinery
50.0002	Misc. Machinery (Except Electrical)
51.0101	Electrical Computing Equipment
53.0100	Instruments to Measure Electricity
53.0200	Transformers
53.0400	Motors & Generators
53.0500	Industrial Controls
53.0700	Carbon & Graphite Products
53.0800	Misc. Electrical Industrial Apperatus
55.0100	Electric Lamps
55.0200	Lighting Fixtures & Equipment
55.0300	Wiring Devices
56.0100	Radio & TV Receiving Sets
*56.0400	Radio & Communication Equipment
57.0100	Electron Tubes
57.0200	Semiconductors & Related Devices
57.0300	Misc. Electronic Components
58.0100	Storage Batteries
58.0400	Engine Electrical Equipment
58.0500	Misc. Electrical Equipment
59.0302	Motor Vehicle Parts & Accessories
60.0100	Aircraft
*60.0200	Aircraft & Missile Engines
*60.0400	Misc. Aircraft & Missile Equipment
62.0100	Engineering & Scientific Instuments
62.0200	Mechanical Measuring Devices
62.0500	Surgical Appliances & Supplies
63.0100	Optical Instruments & Lens

63.0200 Ophthalmic Goods
63.0300 Photographic Equipment & Supplies

APPENDIX F
LISTING OF 'MAJOR INDUSTRIES' THAT MANUFACTURED
COMMODITIES--BY DOLLARS--CRITICAL TO SUPPORT THE SPACE SECTOR

COMMODITY	TOTAL VALUE	2% VALUE	MAJOR PRODUCERS	VALUE PRODUCED
13.0100	4836.80	96.70	13.0100	4415.90
			56.0400	167.90
			60.0200	78.40
			60.0400	90.50
13.0500	729.00	14.60	13.0500	723.40
27.0100	44823.40	896.50	10.0000	814.70
			27.0100	33381.60
			31.0100	6747.70
27.0406	4347.80	87.00	27.0100	218.50
			27.0406	3374.60
			29.0201	91.00
28.0100	12361.80	247.20	27.0100	2387.80
			28.0100	9148.50
28.0200	2354.80	47.10	27.0100	467.90
			28.0100	85.90
			28.0200	1671.00
30.0000	6193.70	123.90	30.0000	5982.50
31.0101	88737.20	1774.40	8.0000	3264.10
			31.0101	84353.30
31.0102	3337.30	66.70	31.0101	1738.50
			31.0102	1529.50
32.0100	9175.80	183.50	32.0100	9095.90
32.0302	4262.10	85.20	32.0100	89.80
			32.0302	3827.90
32.0400	24310.60	486.20	32.0400	22120.70
34.0301	125.20	2.50	18.0400	16.00
			34.0301	107.40
34.0302	590.50	11.80	34.0302	580.50

34.0304	459.10	9.20	34.0304	425.40
34.0305	328.50	6.60	34.0305	316.50
35.0100	5642.10	112.80	35.0100	5344.30
36.0800	383.70	7.70	36.0800	316.80
			38.0700	30.70
			59.0302	10.90
36.1600	1783.90	35.70	36.1600	1730.00
36.1700	968.40	19.40	31.0300	76.10
			36.1700	789.70
			36.1800	25.60
			59.0302	24.70
			64.0900	29.30
36.1800	1269.00	25.40	32.0302	48.90
			36.1800	1130.50
36.1900	1054.70	21.10	9.0004	73.10
			10.0000	44.50
			27.0100	27.20
			36.1900	825.60
36.2200	396.00	7.90	16.0100	16.70
			36.2200	352.00
37.0101	45613.30	912.30	37.0101	39546.60
			37.0104	2588.10
			37.0105	2563.10
37.0200	11233.90	224.70	37.0101	222.00
			37.0200	10231.10
			59.0301	257.40
37.0300	3373.10	67.50	37.0101	430.60
			37.0300	2519.70
			45.0300	73.20
			59.0301	74.10
37.0401	740.40	14.80	37.0401	685.80
37.0402	1049.30	21.00	37.0402	758.10
			38.0700	95.40
			47.0300	35.70
			58.0400	24.90
38.0400	7095.70	141.90	38.0400	5272.50
			38.0600	1177.70
			38.0800	552.80

38.0500	1912.80	38.30	38.0100	427.20
			38.0200	196.50
			38.0500	849.00
			38.0600	393.10
38.0700	3697.60	74.00	38.0700	3410.20
			38.1000	125.70
38.0800	8142.00	162.80	38.0800	7768.90
38.0900	2427.70	48.60	38.0800	54.30
			38.0900	2252.30
38.1000	6952.30	139.00	38.0900	278.80
			38.1000	6056.90
			58.0500	138.70
38.1100	2320.70	46.40	38.1100	2129.60
			38.1200	46.70
			38.1300	67.40
38.1200	625.20	12.50	37.0200	57.50
			38.0700	33.70
			38.1100	37.00
			38.1200	466.00
38.1300	876.50	17.50	38.1100	158.80
			38.1300	678.80
38.1400	598.60	12.00	38.0700	38.40
			38.0800	14.80
			38.1400	419.70
			59.0302	22.80
40.0400	5133.80	102.70	40.0400	4755.90
			40.0600	98.00
40.0700	4830.60	96.60	40.0700	4388.30
40.0902	1347.50	27.00	37.0101	80.00
			40.0400	71.10
			40.0902	1059.60
			59.0302	30.60
41.0100	5028.30	100.60	41.0100	4771.00
41.0203	4669.50	93.40	41.0201	166.00
			41.0203	4105.10
42.0100	667.10	13.30	42.0100	629.50

42.0201	2116.20	42.30	42.0201	1901.30
42.0202	386.10	7.70	42.0201	8.70
			42.0202	301.40
			42.0800	8.30
			44.0002	13.00
42.0300	5185.60	103.70	42.0300	4869.50
42.0401	1866.10	37.30	42.0401	1819.40
42.0402	1621.50	81.10	42.0402	1469.10
42.0500	3852.60	77.10	37.0101	332.40
			37.0103	1087.00
			38.1000	90.70
			42.0500	2081.70
42.0800	7311.70	146.20	42.0800	6591.90
			49.0100	141.90
42.1000	1086.60	21.70	24.0701	104.20
			26.0501	32.30
			38.0800	187.40
			42.1000	689.10
42.1100	3596.10	71.90	37.0101	108.00
			42.1100	3026.90
47.0100	2738.20	54.80	47.0100	2531.60
47.0200	1180.10	23.60	47.0100	34.90
			47.0200	1032.50
			47.0402	22.80
47.0300	7045.10	140.90	41.0201	217.10
			47.0300	5901.20
47.0401	1513.60	30.30	47.0401	1366.90
47.0403	974.60	19.50	47.0402	25.40
			47.0403	808.40

49.0100	5698.40	114.00	49.0100	5146.40
49.0200	2493.90	49.90	49.0200	2443.20
49.0500	2982.30	59.70	49.0500	2425.00
			60.0200	90.10
49.0700	2756.60	55.10	49.0700	2367.30
50.0002	7093.80	141.90	50.0002	6687.50
51.0101	12497.40	249.90	51.0101	11354.40
			57.0300	533.30
53.0100	2724.10	54.50	53.0100	2434.30
			56.0400	95.40
			62.0200	54.20
53.0200	2165.70	43.30	53.0200	2099.00
53.0400	5080.60	101.60	43.0200	330.00
			53.0400	4106.00
			58.0400	95.60
			59.0302	102.20
53.0500	2507.40	50.10	53.0300	126.50
			53.0500	2162.30
53.0700	680.30	13.60	38.0400	31.40
			53.0700	636.60
53.0800	728.30	14.60	51.0400	18.00
			53.0300	18.80
			53.0800	597.90
			57.0300	15.80
55.0100	1643.20	32.90	55.0100	1606.40
55.0200	3353.70	67.10	55.0200	3130.00
55.0300	3201.80	64.00	55.0300	2679.70
56.0100	4797.40	95.90	56.0100	4687.90
56.0400	14887.10	297.70	56.0400	13760.70
57.0100	1316.20	26.30	57.0100	1233.30
			57.0300	37.80
57.0200	4677.20	93.50	57.0200	4406.90
			57.0300	119.20

57.0300	8796.20	175.90	51.0101	376.60
			56.0400	221.80
			57.0300	7104.40
58.0100	1994.70	39.90	58.0100	1974.00
58.0400	3300.70	66.00	58.0400	2975.50
			59.0302	206.00
58.0500	756.20	15.10	41.0203	15.40
			51.0400	18.10
			52.0300	28.20
			58.0500	582.40
59.0302	39073.90	781.50	59.0301	2407.30
			59.0302	34318.20
60.0100	12277.80	245.60	60.0100	11984.40
60.0200	6096.70	121.90	60.0200	5768.20
			60.0400	121.00
60.0400	6814.40	136.30	13.0100	224.40
			60.0100	2195.30
			60.0200	177.90
			60.0400	3928.10
62.0100	1979.00	39.60	27.0100	56.50
			56.0400	57.10
			60.0400	40.10
			62.0100	1596.50
62.0200	4017.50	80.40	42.0800	82.20
			62.0200	3383.20
62.0500	2490.00	49.80	62.0400	123.20
			62.0500	2140.00
63.0100	1345.20	26.90	27.0100	64.00
			62.0100	41.50
			63.0100	1114.80
63.0200	867.80	17.40	63.0200	851.40
63.0300	9486.80	189.70	63.0300	9048.60

APPENDIX G
INDUSTRIES PRODUCING COMMODITIES CRITICAL TO THE SUPPORT OF A SURGE IN THE SPACE SECTOR

BEA CODE	INDUSTRY
8.0000	Crude Petroleum & Natural Gas
9.0004	Nonmetallic Mineral Services
10.0000	Chemical Mineral Mining
13.0100	Complete Guided Missiles
13.0500	Small Arms
16.0100	Broadwoven Fabric Mills
18.0400	Apparel from Purchased Material
24.0701	Paper Coating & Glazing
26.0501	Commercial Printing
27.0100	Inorganic & Organic Chemicals
27.0406	Chemical Preperations
28.0100	Plastic Materials & Resins
28.0200	Synthetic Rubber
29.0201	Soap & other Detergents
30.0000	Paints & Allied Products
30.0101	Petroleum Refining Products
31.0102	Misc. Petroleum Refining Products
31.0300	Aspalt Felt & Coatings
32.0100	Tires & Inner Tubes
32.0302	Fabricated Rubber Products
32.0400	Misc. Plastic Products
32.0500	Rubber & Plastic Hose & Belting
34.0301	Leather Gloves & Mittens
34.0302	Luggage
34.0304	Personal Leather Goods
34.0305	Misc. Leather Goods
35.0100	Glass & Glass Products
36.0800	Porcelain Electric Supplies
36.1600	Abrasive Products
36.1700	Asbestos Products
36.1800	Gaskets, Packing & Sealing Devices
36.1900	Minerals, Ground or Treated
36.2200	Misc. Nonmetallic Mineral Products
37.0101	Blast Furnaces & Stell MMills
37.0103	Steel Wire & Related Products
37.0104	Cold Finishing of Steel Shapes
37.0105	Steel Pipes & Tubes
37.0200	Iron & Steel Foundaries
37.0300	Iron & Steel Forgings
37.0401	Metal & Heat Treating
37.0402	Misc. Primary Metal Products
38.0100	Primary Copper

38.0200	Primary lead
38.0400	Primary Aluminum
38.0500	Misc. Primary Nonferrous Metals
38.0600	Secondary Nonferrous Metals
38.0700	Copper Rollimg & Drawing
38.0400	Primary Aluminum
38.0500	Misc. Primary Nonferrous Metals
38.0700	Copper Rolling & Drawing
38.0800	Aluminum Rolling & Drawing
38.0900	Misc. Nonferrous Rolling & Drawing
38.1000	Nonferrous Wire Drawing & Insulating
38.1100	Aluminum Casting
38.1200	Brass, Bronze, & Copper Casting
38.1300	Misc. Nonferrous Casting
38.1400	Nonferrous Forgings
40.0400	Fabricated Structural Metal
40.0600	Fabricated Plate Work
40.0700	Sheet Metal Work
40.0902	Prefabricated Metal Buildings
41.0100	Screw Machine Products
41.0201	Automotive Stampings
41.0203	Misc. Metal Stampings
42.0100	Cutlery
42.0201	Misc. Hand & Edge Tools
42.0202	Crowns & Closures
42.0300	Misc. Hardware
42.0401	Plating & Polishing
42.0402	Metal Coating & Allied Services
42.0500	Misc. Fabricalted Wire Products
42.0800	Pipe, Valves, & Pipe Fittings
42.1000	Metal Foil & Leaf
42.1100	Misc. Fabricated Metal Products
43.0200	Misc. Internal Combustion Engines
44.0002	Lawn & Garden Equipment
45.0300	Oil Field Machinery
47.0100	Machine Tools, Metal Cutting Types
47.0200	Machine Tools Metal Forming Types
47.0300	Special Dies & Tools
47.0401	Power Driven Hand Tools
47.0402	Rolling Mill Machinery
47.0403	Misc. Metalworking Machinery
49.0100	Pumps & Compressors
49.0200	Ball & Roller Bearings
49.0500	Power Transmsission Equipment
49.0700	Misc. General Industry Machinery
50.0002	Misc. Machinery (Except Electrical)
51.0101	Electrical Computing Equipment
51.0400	Typewritters & Office Machines

52.0300	Refrigeration & Heating Equipment
53.0100	Instruments to Measure Electricity
53.0200	Transformers
53.0300	Switchgear & Switchboard Apperatus
53.0400	Motors & Generators
53.0500	Industrial Controls
53.0700	Carbon & Graphite Products
53.0800	Misc. Electrical Industrial Apperatus
55.0100	Electric Lamps
55.0200	Lighting Fixtures & Equipment
55.0300	Wiring Devices
56.0100	Radio & TV Receiving Sets
56.0400	Radio & Communication Equipment
57.0100	Electron Tubes
57.0200	Semiconductors & Related Devices
57.0300	Misc. Electronic Components
58.0100	Storage Batteries
58.0400	Engine Electrical Equipment
58.0500	Misc. Electrical Equipment
59.0302	Motor Vehicle Parts & Accessories
60.0100	Aircraft
60.0200	Aircraft & Missile Engines
60.0400	Misc. Aircraft & Missile Equipment
62.0100	Engineering & Scientific Instuments
62.0200	Mechanical Measuring Devices
62.0400	Surgical & Medical Instruments
62.0500	Surgical Appliances & Supplies
63.0100	Optical Instruments & Lens
63.0200	Ophthalmic Goods
63.0300	Photographic Equipment
64.0900	Hard Surface Floor Coverings

APPENDIX H
INPUT-OUTPUT COEFFICIENTS BY INDUSTRY
FOR SPACECRAFT AND COMM. EQUIPMENT

INDUSTRY	I-O COEF. (13.0100)	I-O COEF. (56.0400)
Complete Guided Missiles	0.94746	0.01443
Small Arms	0.00006	0.00005
Broadwoven Fabric Mills	0.00146	0.00147
Apparel From Purchased Mater	0.00050	0.00101
Paper Coating & Glazing	0.00101	0.00261
Commercial Printing	0.00171	0.00243
Inorganic & Organic Chemical	0.00933	0.01592
Chemical Preperations	0.00132	0.00341
Plastic Materials & Resins	0.00428	0.00721
Synthetic Rubber	0.00039	0.00069
Soap & Other Detergents	0.00019	0.00029
Paints & Allied Products	0.00115	0.00130
Petroleum Refining Products	0.01274	0.01554
Misc. Petroleum Refining Pro	0.00083	0.00054
Asphalt Felt & Coatings	0.00013	0.00017
Tires & Inner Tubes	0.00066	0.00081
Fabricated Rubber Products	0.00129	0.00160
Misc. Plastic Products	0.01115	0.01872
Rubber & Plastic Hose & Belt	0.00035	0.00057
Leather Gloves & Mittens	0.00000	0.00000
Luggage	0.00000	0.00005
Personal Leather Goods	0.00002	0.00003
Misc. Leather Goods	0.00002	0.00003
Glass & Glass Products	0.00156	0.00531
Porcelain Electric Supplies	0.00025	0.00086
Abrasive Products	0.00157	0.00190
Asbestos Products	0.00017	0.00010
Gaskets, Packing & Sealing D	0.00085	0.00040
Minerals, Ground or Treated	0.00019	0.00037
Misc. Nonmetallic Mineral Pr	0.00038	0.00094
Blast Furnaces & Stell MMill	0.01350	0.02087
Steel Wire & Related Product	0.00050	0.00104
Cold Finishing of Steel Shap	0.00090	0.00139
Steel Pipes & Tubes	0.00087	0.00141
Iron & Steel Foundaries	0.00292	0.00325
Iron & Steel Forgings	0.00191	0.00089
Metal & Heat Treating	0.00089	0.00062
Misc. Primary Metal Products	0.00066	0.00090
Primary Copper	0.00384	0.00648

Primary Lead	0.00056	0.00095
Primary Aluminum	0.00444	0.00621
Misc. Primary Nonferrous Met	0.00159	0.00278
Secondary Nonferrous Metals	0.00280	0.00449
Copper Rolling & Drawing	0.00249	0.00482
Aluminum Rolling & Drawing	0.00563	0.00916
Misc. Nonferrous Rolling & D	0.00572	0.00759
Nonferrous Wire Drawing & In	0.00565	0.00816
Aluminum Casting	0.00252	0.00441
Brass, Bronze, & Copper Cast	0.00025	0.00045
Misc. Nonferrous Casting	0.00109	0.00060
Nonferrous Forgings	0.00133	0.00047
Fabricated Structural Metal	0.00056	0.00156
Fabricated Plate Work	0.00085	0.00070
Sheet Metal Work	0.00130	0.00593
Prefabricated Metal Building	0.00057	0.00321
Screw Machine Products	0.00382	0.00719
Automotive Stampings	0.00055	0.00073
Misc. Metal Stampings	0.00386	0.00672
Cutlery	0.00005	0.00006
Misc. Hand & Edge Tools	0.00057	0.00055
Hand Saw & Saw Blades	0.00009	0.00007
Misc. Hardware	0.00085	0.00083
Plating & Polishing	0.00434	0.01205
Metal Coating & Allied Servi	0.00146	0.00208
Misc. Fabricalted Wire Produ	0.00047	0.00127
Pipe, Valves, & Pipe Fitting	0.00084	0.00127
Metal Foil & Leaf	0.00055	0.00017
Misc. Fabricated Metal Produ	0.00199	0.00294
Misc. Internal Combustion En	0.00099	0.00095
Lawn & Garden Equipment	0.00003	0.00004
Oil Field Machinery	0.00026	0.00047
Machine Tools, Metal Cutting	0.00071	0.00041
Machine Tools Metal Forming	0.00017	0.00029
Special Dies & Tools	0.00397	0.00493
Power Driven Hand Tools	0.00011	0.00011
Rolling Mill Machinery	0.00003	0.00004
Misc. Metalworking Machinery	0.00019	0.00045
Pumps & Compressors	0.00454	0.00071
Ball & Roller Bearings	0.00118	0.00068
Power Transmsission Equipmen	0.00064	0.00075
Misc. General Industry Machi	0.00035	0.00130
Misc. Machinery (Except Elec	0.00894	0.00772
Electrical Computing Equipme	0.00338	0.01131
Typewritters & Office Machin	0.00079	0.00283
Refrigeration & Heating Equi	0.00051	0.00058
Instruments to Measure Elect	0.00206	0.00832
Transformers	0.00038	0.00147

Switchgear & Switchboard App	0.00039	0.00112
Motors & Generators	0.00480	0.00389
Industrial Controls	0.00129	0.00486
Carbon & Graphite Products	0.00460	0.00068
Misc. Electrical Industrial	0.00029	0.00099
Electric Lamps	0.00026	0.00036
Lighting Fixtures & Equipmen	0.00076	0.00452
Wiring Devices	0.00145	0.00535
Radio & TV Receiving Sets	0.01763	0.00904
Radio & Communication Equipm	0.15846	0.93972
Electron Tubes	0.00409	0.01496
Semiconductors & Related Dev	0.01352	0.05368
Misc. Electronic Components	0.03275	0.11321
Storage Batteries	0.00009	0.00024
Engine Electrical Equipment	0.00094	0.00201
Misc. Electrical Equipment	0.00073	0.00033
Motor Vehicle Parts & Access	0.00498	0.00351
Aircraft	0.02558	0.00575
Aircraft & Missile Engines	0.02630	0.00201
Misc. Aircraft & Missile Equ	0.05596	0.00412
Engineering & Scientific Ins	0.00106	0.00265
Mechanical Measuring Devices	0.00093	0.00344
Surgical & Medical Instrumen	0.00007	0.00017
Surgical Appliances & Suppli	0.00042	0.00097
Optical Instruments & Lens	0.00117	0.00282
Ophthalmic Goods	0.00004	0.00010
Photographic Equipment & Sup	0.00394	0.00512
Hard Surface Floor Coverings	0.00001	0.00002

APPENDIX H CONT.
INPUT-OUTPUT COEFFICIENTS BY INDUSTRY
FOR MISSILE ENGINES AND MISC. MISSILE EQUIPMENT

INDUSTRY	I-O COEF. (60.0200)	I-O COEF. (60.0400)
Complete Guided Missiles	0.00810	0.03904
Small Arms	0.00009	0.00009
Broadwoven Fabric Mills	0.00384	0.00544
Apparel From Purchased Material	0.00052	0.00088
Paper Coating & Glazing	0.00064	0.00087
Commercial Printing	0.00230	0.00255
Inorganic & Organic Chemicals	0.01225	0.01429
Chemical Preperations	0.00138	0.00213
Plastic Materials & Resins	0.00288	0.00521
Synthetic Rubber	0.00068	0.00053
Soap & Other Detergents	0.00031	0.00020
Paints & Allied Products	0.00149	0.00244
Petroleum Refining Products	0.02650	0.01945
Misc. Petroleum Refining Products	0.00083	0.00084
Asphalt Felt & Coatings	0.00095	0.00047
Tires & Inner Tubes	0.00114	0.00111
Fabricated Rubber Products	0.00566	0.00288
Misc. Plastic Products	0.00790	0.01156
Rubber & Plastic Hose & Belting	0.00055	0.00040
Leather Gloves & Mittens	0.00000	0.00000
Luggage	0.00006	0.00005
Personal Leather Goods	0.00002	0.00010
Misc. Leather Goods	0.00002	0.00002
Glass & Glass Products	0.00083	0.00193
Porcelain Electric Supplies	0.00100	0.00023
Abrasive Products	0.00226	0.00283
Asbestos Products	0.00021	0.00123
Gaskets, Packing & Sealing Devices	0.00090	0.00072
Minerals, Ground or Treated	0.00020	0.00023
Misc. Nonmetallic Mineral Products	0.00064	0.00071
Blast Furnaces & Stell MMills	0.05363	0.03231
Steel Wire & Related Products	0.00133	0.00116
Cold Finishing of Steel Shapes	0.00318	0.00209
Steel Pipes & Tubes	0.00310	0.00201
Iron & Steel Foundaries	0.02038	0.00666
Iron & Steel Forgings	0.03355	0.00813
Metal & Heat Treating	0.00216	0.00205
Misc. Primary Metal Products	0.00156	0.00086
Primary Copper	0.00658	0.00551

Primary Lead	0.00120	0.00086
Primary Aluminum	0.02451	0.01178
Misc. Primary Nonferrous Metals	0.00325	0.00231
Secondary Nonferrous Metals	0.00944	0.00546
Copper Rolling & Drawing	0.00412	0.00395
Aluminum Rolling & Drawing	0.01001	0.01876
Misc. Nonferrous Rolling & Drawing	0.01155	0.00759
Nonferrous Wire Drawing & Insulatin	0.00299	0.00559
Aluminum Casting	0.01233	0.00566
Brass, Bronze, & Copper Casting	0.00094	0.00072
Misc. Nonferrous Casting	0.00892	0.00261
Nonferrous Forgings	0.01286	0.00637
Fabricated Structural Metal	0.00530	0.00024
Fabricated Plate Work	0.00180	0.00766
Sheet Metal Work	0.00060	0.00089
Prefabricated Metal Buildings	0.00009	0.00026
Screw Machine Products	0.00636	0.01090
Automotive Stampings	0.00127	0.00094
Misc. Metal Stampings	0.00469	0.00576
Cutlery	0.00016	0.00007
Misc. Hand & Edge Tools	0.00426	0.00101
Hand Saw & Saw Blades	0.00078	0.00020
Misc. Hardware	0.00219	0.00372
Plating & Polishing	0.00203	0.00564
Metal Coating & Allied Services	0.00142	0.00187
Misc. Fabricalted Wire Products	0.00079	0.00108
Pipe, Valves, & Pipe Fittings	0.00505	0.00161
Metal Foil & Leaf	0.00009	0.00017
Misc. Fabricated Metal Products	0.00194	0.00284
Misc. Internal Combustion Engines	0.00415	0.00140
Lawn & Garden Equipment	0.00009	0.00005
Oil Field Machinery	0.00119	0.00045
Machine Tools, Metal Cutting Types	0.00288	0.00222
Machine Tools Metal Forming Types	0.00052	0.00049
Special Dies & Tools	0.01723	0.00964
Power Driven Hand Tools	0.00021	0.00093
Rolling Mill Machinery	0.00014	0.00006
Misc. Metalworking Machinery	0.00109	0.00074
Pumps & Compressors	0.00319	0.00445
Ball & Roller Bearings	0.00781	0.00414
Power Transmsission Equipment	0.00125	0.00256
Misc. General Industry Machinery	0.00047	0.00041
Misc. Machinery (Except Electrical)	0.02083	0.01518
Electrical Computing Equipment	0.00164	0.00481
Typewritters & Office Machines	0.00052	0.00357
Refrigeration & Heating Equipment	0.00067	0.00058
Instruments to Measure Electricity	0.00029	0.00110
Transformers	0.00035	0.00031

Switchgear & Switchboard Apperatus	0.00041	0.00043
Motors & Generators	0.00239	0.00287
Industrial Controls	0.00091	0.00139
Carbon & Graphite Products	0.00086	0.00067
Misc. Electrical Industrial Apperat	0.00016	0.00023
Electric Lamps	0.00025	0.00027
Lighting Fixtures & Equipment	0.00033	0.00051
Wiring Devices	0.00072	0.00093
Radio & TV Receiving Sets	0.00037	0.00084
Radio & Communication Equipment	0.01065	0.05789
Electron Tubes	0.00063	0.00043
Semiconductors & Related Devices	0.00306	0.01858
Misc. Electronic Components	0.01607	0.02343
Storage Batteries	0.00012	0.00014
Engine Electrical Equipment	0.00370	0.00472
Misc. Electrical Equipment	0.00023	0.00027
Motor Vehicle Parts & Accessories	0.00777	0.00358
Aircraft	0.02477	0.36480
Aircraft & Missile Engines	1.03646	0.07077
Misc. Aircraft & Missile Equipment	0.05556	0.64319
Engineering & Scientific Instuments	0.00028	0.00235
Mechanical Measuring Devices	0.00133	0.00424
Surgical & Medical Instruments	0.00005	0.00031
Surgical Appliances & Supplies	0.00035	0.00126
Optical Instruments & Lens	0.00202	0.00573
Ophthalmic Goods	0.00012	0.00019
Photographic Equipment & Supplies	0.00264	0.00501
Hard Surface Floor Coverings	0.00002	0.00004

APPENDIX I

PERCENT INCREASE IN PRODUCTION REQUIRED FOR EACH INDUSTRY TO SUPPORT A 100 PERCENT INCREASE IN THE FINAL DEMAND FOR SPACECRAFT AND COMM. EQUIPMENT

INDUSTRY	TOTAL REQUIR. (13.0100)	TOTAL REQUIR. (56.0400)
Complete Guided Missiles	86.33	0.63
Small Arms	0.05	0.02
Broadwoven Fabric Mills	0.08	0.03
Apparel From Purchased Material	0.01	0.01
Paper Coating & Glazing *	0.17	0.21
Commercial Printing *	0.05	0.04
Inorganic & Organic Chemicals	0.21	0.17
Chemical Preperations	0.19	0.24
Plastic Materials & Resins	0.25	0.20
Synthetic Rubber	0.11	0.09
Soap & Other Detergents	0.01	0.01
Paints & Allied Products	0.11	0.06
Petroleum Refining Products	0.06	0.03
Misc. Petroleum Refining Products	0.24	0.07
Asphalt Felt & Coatings	0.04	0.02
Tires & Inner Tubes	0.06	0.03
Fabricated Rubber Products	1.70	1.01
Misc. Plastic Products	0.28	0.22
Rubber & Plastic Hose & Belting	0.14	0.11
Leather Gloves & Mittens	0.00	0.00
Luggage	0.00	0.02
Personal Leather Goods	0.04	0.03
Misc. Leather Goods	0.05	0.04
Glass & Glass Products	0.19	0.32
Porcelain Electric Supplies	0.44	0.73
Abrasive Products	0.53	0.31
Asbestos Products	0.18	0.05
Gaskets, Packing & Sealing Devices	0.47	0.10
Minerals, Ground or Treated	0.14	0.13
Misc. Nonmetallic Mineral Products	0.83	1.00
Blast Furnaces & Stell MMills	0.34	0.25
Steel Wire & Related Products	0.19	0.19
Cold Finishing of Steel Shapes	0.27	0.20
Steel Pipes & Tubes	0.21	0.16
Iron & Steel Foundaries	0.83	0.44
Iron & Steel Forgings	0.60	0.13
Metal & Heat Treating	0.73	0.24
Misc. Primary Metal Products	0.65	0.43

Primary Copper	1.16	0.94
Primary Lead	0.93	0.76
Primary Aluminum	0.82	0.55
Misc. Primary Nonferrous Metals	0.50	0.42
Secondary Nonferrous Metals	0.53	0.41
Copper Rolling & Drawing	0.68	0.64
Aluminum Rolling & Drawing	0.49	0.39
Misc. Nonferrous Rolling & Drawing	1.60	1.02
Nonferrous Wire Drawing & Insulatin	0.66	0.46
Aluminum Casting	0.77	0.65
Brass, Bronze, & Copper Casting	0.33	0.28
Misc. Nonferrous Casting	1.19	0.31
Nonferrous Forgings	1.13	0.19
Fabricated Structural Metal	0.06	0.08
Fabricated Plate Work	0.10	0.03
Sheet Metal Work	0.17	0.38
Prefabricated Metal Buildings	0.22	0.62
Screw Machine Products	1.05	0.95
Automotive Stampings	0.05	0.03
Misc. Metal Stampings	0.55	0.46
Cutlery	0.04	0.02
Misc. Hand & Edge Tools	0.18	0.08
Hand Saw & Saw Blades	0.16	0.06
Misc. Hardware	0.13	0.06
Plating & Polishing	1.48	1.98
Metal Coating & Allied Services	0.56	0.39
Misc. Fabricalted Wire Products	0.12	0.16
Pipe, Valves, & Pipe Fittings	0.08	0.06
Metal Foil & Leaf	0.27	0.04
Misc. Fabricated Metal Products	0.37	0.26
Misc. Internal Combustion Engines	0.10	0.04
Lawn & Garden Equipment	0.01	0.00
Oil Field Machinery	0.02	0.01
Machine Tools, Metal Cutting Types	0.14	0.03
Machine Tools Metal Forming Types	0.11	0.09
Special Dies & Tools	0.51	0.31
Power Driven Hand Tools	0.05	0.02
Rolling Mill Machinery	0.05	0.03
Misc. Metalworking Machinery	0.12	0.13
Pumps & Compressors	0.46	0.03
Ball & Roller Bearings	0.35	0.09
Power Transmsission Equipment	0.17	0.09
Misc. General Industry Machinery	0.07	0.13
Misc. Machinery (Except Electrical)	0.65	0.27
Electrical Computing Equipment	0.08	0.14
Typewritters & Office Machines	0.18	0.31
Refrigeration & Heating Equipment	0.03	0.02
Instruments to Measure Electricity	0.30	0.59

Transformers	0.11	0.21
Switchgear & Switchboard Apperatus	0.07	0.10
Motors & Generators	0.74	0.29
Industrial Controls	0.28	0.51
Carbon & Graphite Products	4.37	0.31
Misc. Electrical Industrial Apperat	0.24	0.40
Electric Lamps	0.11	0.07
Lighting Fixtures & Equipment	0.17	0.50
Wiring Devices	0.27	0.48
Radio & TV Receiving Sets	2.70	0.66
Radio & Communication Equipment	11.46	32.77
Electron Tubes	1.71	3.03
Semiconductors & Related Devices	0.94	1.81
Misc. Electronic Components	1.68	2.80
Storage Batteries	0.03	0.04
Engine Electrical Equipment	0.26	0.26
Misc. Electrical Equipment	0.54	0.11
Motor Vehicle Parts & Accessories	1.27	0.43
Aircraft	0.85	0.09
Aircraft & Missile Engines	11.13	0.41
Misc. Aircraft & Missile Equipment	26.78	0.95
Engineering & Scientific Instuments	0.28	0.34
Mechanical Measuring Devices	0.13	0.23
Surgical & Medical Instruments	0.01	0.01
Surgical Appliances & Supplies	0.07	0.08
Optical Instruments & Lens	0.33	0.38
Ophthalmic Goods	0.03	0.03
Photographic Equipment & Supplies	0.21	0.13
Hard Surface Floor Coverings	0.01	0.01

APPENDIX I CONT.
PERCENT INCREASE IN PRODUCTION FOR EACH
INDUSTRY TO SUPPORT A 100 PERCENT INCREASE IN THE
FINAL DEMAND OF MISSILE ENGINES AND MISC. MISSILE EQUIPMENT

INDUSTRY	TOTAL REQUIR. (60.0200)	TOTAL REQUIR. (60.0400)
Complete Guided Missiles	0.16	0.71
Small Arms	0.01	0.01
Broadwoven Fabric Mills	0.04	0.06
Apparel From Purchased Material	0.00	0.00
Paper Coating & Glazing *	0.02	0.02
Commercial Printing *	0.01	0.01
Inorganic & Organic Chemicals	0.06	0.06
Chemical Preperations	0.04	0.06
Plastic Materials & Resins	0.03	0.06
Synthetic Rubber	0.04	0.03
Soap & Other Detergents	0.00	0.00
Paints & Allied Products	0.03	0.04
Petroleum Refining Products	0.02	0.01
Misc. Petroleum Refining Products	0.05	0.04
Asphalt Felt & Coatings	0.06	0.03
Tires & Inner Tubes	0.02	0.02
Fabricated Rubber Products	1.66	0.75
Misc. Plastic Products	0.04	0.05
Rubber & Plastic Hose & Belting	0.05	0.03
Leather Gloves & Mittens	0.00	0.00
Luggage	0.01	0.01
Personal Leather Goods	0.01	0.04
Misc. Leather Goods	0.01	0.01
Glass & Glass Products	0.02	0.01
Porcelain Electric Supplies	0.39	0.08
Abrasive Products	0.17	0.19
Asbestos Products	0.05	0.27
Gaskets, Packing & Sealing Devices	0.11	0.08
Minerals, Ground or Treated	0.03	0.03
Misc. Nonmetallic Mineral Products	0.31	0.31
Blast Furnaces & Stell MMills	0.30	0.16
Steel Wire & Related Products	0.11	0.08
Cold Finishing of Steel Shapes	0.22	0.12
Steel Pipes & Tubes	0.17	0.09
Iron & Steel Foundaries	1.30	0.38
Iron & Steel Forgings	2.38	0.51
Metal & Heat Treating	0.39	0.33
Misc. Primary Metal Products	0.34	0.17

Primary Copper	0.44	0.33
Primary Lead	0.44	0.28
Primary Aluminum	1.01	0.43
Misc. Primary Nonferrous Metals	0.22	0.14
Secondary Nonferrous Metals	0.40	0.20
Copper Rolling & Drawing	0.25	0.21
Aluminum Rolling & Drawing	0.19	0.33
Misc. Nonferrous Rolling & Drawing	0.72	0.42
Nonferrous Wire Drawing & Insulating	0.07	0.13
Aluminum Casting	0.84	0.34
Brass, Bronze, & Copper Casting	0.27	0.19
Misc. Nonferrous Casting	2.18	0.57
Nonferrous Forgings	2.45	1.08
Fabricated Structural Metal	0.12	0.00
Fabricated Plate Work	0.04	0.18
Sheet Metal Work	0.01	0.02
Prefabricated Metal Buildings	0.00	0.02
Screw Machine Products	0.39	0.60
Automotive Stampings	0.03	0.01
Misc. Metal Stampings	0.15	0.16
Cutlery	0.03	0.01
Misc. Hand & Edge Tools	0.30	0.06
Hand Saw & Saw Blades	0.32	0.07
Misc. Hardware	0.07	0.12
Plating & Polishing	0.15	0.38
Metal Coating & Allied Services	0.12	0.14
Misc. Fabricalted Wire Products	0.04	0.05
Pipe, Valves, & Pipe Fittings	0.11	0.03
Metal Foil & Leaf	0.01	0.01
Misc. Fabricated Metal Products	0.08	0.10
Misc. Internal Combustion Engines	0.09	0.02
Lawn & Garden Equipment	0.00	0.00
Oil Field Machinery	0.02	0.00
Machine Tools, Metal Cutting Types	0.12	0.08
Machine Tools Metal Forming Types	0.07	0.06
Special Dies & Tools	0.50	0.25
Power Driven Hand Tools	0.02	0.09
Rolling Mill Machinery	0.05	0.02
Misc. Metalworking Machinery	0.15	0.09
Pumps & Compressors	0.07	0.09
Ball & Roller Bearings	0.52	0.24
Power Transmsission Equipment	0.07	0.13
Misc. General Industry Machinery	0.02	0.01
Misc. Machinery (Except Electrical)	0.33	0.22
Electrical Computing Equipment	0.00	0.02
Typewritters & Office Machines	0.02	0.16
Refrigeration & Heating Equipment	0.01	0.00
Instruments to Measure Electricity	0.00	0.03

Transformers	0.02	0.01
Switchgear & Switchboard Apperatus	0.01	0.01
Motors & Generators	0.08	0.08
Industrial Controls	0.04	0.06
Carbon & Graphite Products	0.18	0.12
Misc. Electrical Industrial Apperatu	0.02	0.03
Electric Lamps	0.02	0.02
Lighting Fixtures & Equipment	0.01	0.02
Wiring Devices	0.03	0.03
Radio & TV Receiving Sets	0.01	0.02
Radio & Communication Equipment	0.17	0.83
Electron Tubes	0.05	0.03
Semiconductors & Related Devices	0.04	0.25
Misc. Electronic Components	0.18	0.24
Storage Batteries	0.01	0.01
Engine Electrical Equipment	0.22	0.26
Misc. Electrical Equipment	0.03	0.04
Motor Vehicle Parts & Accessories	0.44	0.18
Aircraft	0.18	2.44
Aircraft & Missile Engines	97.99	5.98
Misc. Aircraft & Missile Equipment	5.94	61.54
Engineering & Scientific Instuments	0.01	0.12
Mechanical Measuring Devices	0.04	0.11
Surgical & Medical Instruments	0.00	0.01
Surgical Appliances & Supplies	0.01	0.04
Optical Instruments & Lens	0.12	0.32
Ophthalmic Goods	0.02	0.03
Photographic Equipment & Supplies	0.03	0.05
Hard Surface Floor Coverings	0.00	0.01

APPENDIX J

TOTAL PERCENT INCREASE IN PRODUCTION BY INDUSTRY TO SUPPORT AN OVERALL 100 PERCENT INCREASE I IN THE FINAL DEMAND OF ALL SPACE PRODUCTS

INDUSTRY	SUM OF TOTAL REQUIR.
Complete Guided Missiles	87.84
Small Arms	0.11
Broadwoven Fabric Mills	0.22
Apparel From Purchased Material	0.02
Paper Coating & Glazing *	0.44
Commercial Printing *	0.13
Inorganic & Organic Chemicals	0.51
Chemical Preperations	0.54
Plastic Materials & Resins	0.55
Synthetic Rubber	0.29
Soap & Other Detergents	0.04
Paints & Allied Products	0.26
Petroleum Refining Products	0.14
Misc. Petroleum Refining Products	0.42
Asphalt Felt & Coatings	0.16
Tires & Inner Tubes	0.15
Fabricated Rubber Products	5.14
Misc. Plastic Products	0.61
Rubber & Plastic Hose & Belting	0.34
Leather Gloves & Mittens	0.00
Luggage	0.05
Personal Leather Goods	0.13
Misc. Leather Goods	0.12
Glass & Glass Products	0.59
Porcelain Electric Supplies	1.64
Abrasive Products	1.20
Asbestos Products	0.56
Gaskets, Packing & Sealing Devices	0.77
Minerals, Ground or Treated	0.34
Misc. Nonmetallic Mineral Products	2.46
Blast Furnaces & Stell MMills	1.06
Steel Wire & Related Products	0.59
Cold Finishing of Steel Shapes	0.83
Steel Pipes & Tubes	0.65
Iron & Steel Foundaries	2.97
Iron & Steel Forgings	3.64
Metal & Heat Treating	1.71
Misc. Primary Metal Products	1.60

Primary Copper	2.88
Primary Lead	2.42
Primary Aluminum	2.82
Misc. Primary Nonferrous Metals	1.30
Secondary Nonferrous Metals	1.56
Copper Rolling & Drawing	1.80
Aluminum Rolling & Drawing	1.42
Misc. Nonferrous Rolling & Drawing	3.78
Nonferrous Wire Drawing & Insulating	1.34
Aluminum Casting	2.61
Brass, Bronze, & Copper Casting	1.08
Misc. Nonferrous Casting	4.27
Nonferrous Forgings	4.86
Fabricated Structural Metal	0.27
Fabricated Plate Work	0.36
Sheet Metal Work	0.60
Prefabricated Metal Buildings	0.88
Screw Machine Products	3.00
Automotive Stampings	0.14
Misc. Metal Stampings	1.34
Cutlery	0.12
Misc. Hand & Edge Tools	0.63
Hand Saw & Saw Blades	0.63
Misc. Hardware	0.40
Plating & Polishing	4.00
Metal Coating & Allied Services	1.22
Misc. Fabricalted Wire Products	0.39
Pipe, Valves, & Pipe Fittings	0.29
Metal Foil & Leaf	0.34
Misc. Fabricated Metal Products	0.82
Misc. Internal Combustion Engines	0.27
Lawn & Garden Equipment	0.03
Oil Field Machinery	0.07
Machine Tools, Metal Cutting Types	0.39
Machine Tools Metal Forming Types	0.34
Special Dies & Tools	1.58
Power Driven Hand Tools	0.20
Rolling Mill Machinery	0.17
Misc. Metalworking Machinery	0.50
Pumps & Compressors	0.66
Ball & Roller Bearings	1.23
Power Transmsission Equipment	0.48
Misc. General Industry Machinery	0.25
Misc. Machinery (Except Electrical)	1.48
Electrical Computing Equipment	0.26
Typewritters & Office Machines	0.69
Refrigeration & Heating Equipment	0.07
Instruments to Measure Electricity	0.95

Transformers	0.37
Switchgear & Switchboard Apperatus	0.20
Motors & Generators	1.20
Industrial Controls	0.91
Carbon & Graphite Products	4.99
Misc. Electrical Industrial Apperatu	0.71
Electric Lamps	0.24
Lighting Fixtures & Equipment	0.71
Wiring Devices	0.82
Radio & TV Receiving Sets	3.41
Radio & Communication Equipment	45.24
Electron Tubes	4.84
Semiconductors & Related Devices	3.06
Misc. Electronic Components	4.90
Storage Batteries	0.10
Engine Electrical Equipment	1.02
Misc. Electrical Equipment	0.74
Motor Vehicle Parts & Accessories	2.33
Aircraft	3.58
Aircraft & Missile Engines	115.52
Misc. Aircraft & Missile Equipment	95.22
Engineering & Scientific Instuments	0.77
Mechanical Measuring Devices	0.52
Surgical & Medical Instruments	0.05
Surgical Appliances & Supplies	0.21
Optical Instruments & Lens	1.18
Ophthalmic Goods	0.12
Photographic Equipment & Supplies	0.43
Hard Surface Floor Coverings	0.04

APPENDIX K
1982 PREFERRED & PRACTICAL CAPACITY RATES BY INDUSTRY

INDUSTRY	PREFERRED RATE 1982	PRACTICAL RATE 1982
Complete Guided Missiles	73	63
Small Arms	51	47
Broadwoven Fabric Mills	85	84
Apparel From Purchased Material	83	79
Paper Coating & Glazing	79	74
Commercial Printing	78	72
Inorganic & Organic Chemicals	66	62
Chemical Preperations	61	50
Plastic Materials & Resins	66	54
Synthetic Rubber	65	60
Soap & Other Detergents	73	70
Paints & Allied Products	65	59
Petroleum Refining Products	80	73
Misc. Petroleum Refining Products	66	62
Asphalt Felt & Coatings	60	56
Tires & Inner Tubes	76	76
Fabricated Rubber Products	60	55
Misc. Plastic Products	68	63
Rubber & Plastic Hose & Belting	67	57
Leather Gloves & Mittens	88	88
Luggage	63	54
Personal Leather Goods	64	59
Misc. Leather Goods	72	56
Glass & Glass Products	67	64
Porcelain Electric Supplies	66	55
Abrasive Products	67	53
Asbestos Products	65	56
Gaskets, Packing & Sealing Devices	57	38
Minerals, Ground or Treated	66	65
Misc. Nonmetallic Mineral Products	43	39
Blast Furnaces & Stell MMills	45	44
Steel Wire & Related Products	46	44
Cold Finishing of Steel Shapes	42	38
Steel Pipes & Tubes	37	34
Iron & Steel Foundaries	39	34
Iron & Steel Forgings	33	30
Metal & Heat Treating	96	96
Misc. Primary Metal Products	71	68
Primary Copper	67	67
Primary Lead	77	74

Primary Aluminum	64	60
Misc. Primary Nonferrous Metals	71	71
Secondary Nonferrous Metals	60	50
Copper Rolling & Drawing	55	52
Aluminum Rolling & Drawing	71	70
Misc. Nonferrous Rolling & Drawing	62	56
Nonferrous Wire Drawing & Insulatin	66	63
Aluminum Casting	43	40
Brass, Bronze, & Copper Casting	70	58
Misc. Nonferrous Casting	58	43
Nonferrous Forgings	51	51
Fabricated Structural Metal	60	47
Fabricated Plate Work	47	41
Sheet Metal Work	55	50
Prefabricated Metal Buildings	65	52
Screw Machine Products	59	50
Automotive Stampings	59	55
Misc. Metal Stampings	59	54
Cutlery	74	63
Misc. Hand & Edge Tools	61	53
Hand Saw & Saw Blades	57	32
Misc. Hardware	74	63
Plating & Polishing	57	54
Metal Coating & Allied Services	38	37
Misc. Fabricalted Wire Products	90	86
Pipe, Valves, & Pipe Fittings	72	59
Metal Foil & Leaf	68	68
Misc. Fabricated Metal Products	63	59
Misc. Internal Combustion Engines	40	38
Lawn & Garden Equipment	59	51
Oil Field Machinery	56	52
Machine Tools, Metal Cutting Types	44	41
Machine Tools Metal Forming Types	51	45
Special Dies & Tools	69	64
Power Driven Hand Tools	48	41
Rolling Mill Machinery	48	48
Misc. Metalworking Machinery	56	45
Pumps & Compressors	63	57
Ball & Roller Bearings	49	45
Power Transmsission Equipment	57	49
Misc. General Industry Machinery	71	66
Misc. Machinery (Except Electrical)	72	55
Electrical Computing Equipment	71	64
Typewritters & Office Machines	75	72
Refrigeration & Heating Equipment	63	58
Instruments to Measure Electricity	80	68
Transformers	58	53
Switchgear & Switchboard Apperatus	67	63

Motors & Generators	51	41
Industrial Controls	61	56
Carbon & Graphite Products	45	41
Misc. Electrical Industrial Apperat	72	59
Electric Lamps	47	44
Lighting Fixtures & Equipment	76	74
Wiring Devices	62	59
Radio & TV Receiving Sets	65	59
Radio & Communication Equipment	77	67
Electron Tubes	80	74
Semiconductors & Related Devices	77	72
Misc. Electronic Components	74	66
Storage Batteries	76	72
Engine Electrical Equipment	62	55
Misc. Electrical Equipment	54	47
Motor Vehicle Parts & Accessories	56	50
Aircraft	49	45
Aircraft & Missile Engines	75	64
Misc. Aircraft & Missile Engines	62	54
Engineering & Scientific Instuments	57	51
Mechanical Measuring Devices	72	59
Surgical & Medical Instruments	73	72
Surgical Appliances & Supplies	71	70
Optical Instruments & Lens	79	68
Ophthalmic Goods	72	54
Photographic Equipment & Supplies	84	76
Hard Surface Floor Coverings	70	70

APPENDIX L
LISTING OF EACH INDUSTRY'S CAPACITY TO INCREASE PRODUCTION BASED ON 1982 PREFERRED & PRACTICAL CAPACITY RATES

INDUSTRY	%INCREASE CAPABLE (82-PERF)	%INCREASE CAPABLE (82-PRACT)
Complete Guided Missiles	36.9	58.7
Small Arms	96.0	112.7
Broadwoven Fabric Mills	17.6	19.0
Apparel From Purchased Material	20.4	26.5
Paper Coating & Glazing	26.5	35.1
Commercial Printing	28.2	38.8
Inorganic & Organic Chemicals	51.5	61.2
Chemical Preperations	63.9	100.0
Plastic Materials & Resins	51.5	85.1
Synthetic Rubber	53.8	66.6
Soap & Other Detergents	36.9	42.8
Paints & Allied Products	53.8	69.4
Petroleum Refining Products	25.0	36.9
Misc. Petroleum Refining Products	51.5	61.2
Asphalt Felt & Coatings	66.6	78.5
Tires & Inner Tubes	31.5	31.5
Fabricated Rubber Products	66.6	81.8
Misc. Plastic Products	47.0	58.7
Rubber & Plastic Hose & Belting	49.2	75.4
Leather Gloves & Mittens	13.6	13.6
Luggage	58.7	85.1
Personal Leather Goods	56.2	69.4
Misc. Leather Goods	38.8	78.5
Glass & Glass Products	49.2	56.2
Porcelain Electric Supplies	51.5	81.8
Abrasive Products	49.2	88.6
Asbestos Products	53.8	78.5
Gaskets, Packing & Sealing Devices	75.4	163.1
Minerals, Ground or Treated	51.5	53.8
Misc. Nonmetallic Mineral Products	132.5	156.4
Blast Furnaces & Stell MMills	122.2	127.2
Steel Wire & Related Products	117.3	127.2
Cold Finishing of Steel Shapes	138.0	163.1
Steel Pipes & Tubes	170.2	194.1
Iron & Steel Foundaries	156.4	194.1
Iron & Steel Forgings	203.0	233.3
Metal & Heat Treating	4.1	4.1
Misc. Primary Metal Products	40.8	47.0
Primary Copper	49.2	49.2

Primary Lead	29.8	35.1
Primary Aluminum	56.2	66.6
Misc. Primary Nonferrous Metals	40.8	40.8
Secondary Nonferrous Metals	66.6	100.0
Copper Rolling & Drawing	81.8	92.3
Aluminum Rolling & Drawing	40.8	42.8
Misc. Nonferrous Rolling & Drawing	61.2	78.5
Nonferrous Wire Drawing & Insulating	51.5	58.7
Aluminum Casting	132.5	150.0
Brass, Bronze, & Copper Casting	42.8	72.4
Misc. Nonferrous Casting	72.4	132.5
Nonferrous Forgings	96.0	96.0
Fabricated Structural Metal	66.6	112.7
Fabricated Plate Work	112.7	143.9
Sheet Metal Work	81.8	100.0
Prefabricated Metal Buildings	53.8	92.3
Screw Machine Products	69.4	100.0
Automotive Stampings	69.4	81.8
Misc. Metal Stampings	69.4	85.1
Cutlery	35.1	58.7
Misc. Hand & Edge Tools	63.9	88.6
Hand Saw & Saw Blades	75.4	212.5
Misc. Hardware	35.1	58.7
Plating & Polishing	75.4	85.1
Metal Coating & Allied Services	163.1	170.2
Misc. Fabricalted Wire Products	11.1	16.2
Pipe, Valves, & Pipe Fittings	38.8	69.4
Metal Foil & Leaf	47.0	47.0
Misc. Fabricated Metal Products	58.7	69.4
Misc. Internal Combustion Engines	150.0	163.1
Lawn & Garden Equipment	69.4	96.0
Oil Field Machinery	78.5	92.3
Machine Tools, Metal Cutting Types	127.2	143.9
Machine Tools Metal Forming Types	96.0	122.2
Special Dies & Tools	44.9	56.2
Power Driven Hand Tools	108.3	143.9
Rolling Mill Machinery	108.3	108.3
Misc. Metalworking Machinery	78.5	122.2
Pumps & Compressors	58.7	75.4
Ball & Roller Bearings	104.0	122.2
Power Transmsission Equipment	75.4	104.0
Misc. General Industry Machinery	40.8	51.5
Misc. Machinery (Except Electrical)	38.8	81.8
Electrical Computing Equipment	40.8	56.2
Typewritters & Office Machines	33.3	38.8
Refrigeration & Heating Equipment	58.7	72.4
Instruments to Measure Electricity	25.0	47.0
Transformers	72.4	88.6

Switchgear & Switchboard Apperatus	49.2	58.7
Motors & Generators	96.0	143.9
Industrial Controls	63.9	78.5
Carbon & Graphite Products	122.2	143.9
Misc. Electrical Industrial Apperatu	38.8	69.4
Electric Lamps	112.7	127.2
Lighting Fixtures & Equipment	31.5	35.1
Wiring Devices	61.2	69.4
Radio & TV Receiving Sets	53.8	69.4
Radio & Communication Equipment	29.8	49.2
Electron Tubes	25.0	35.1
Semiconductors & Related Devices	29.8	38.8
Misc. Electronic Components	35.1	51.5
Storage Batteries	31.5	38.8
Engine Electrical Equipment	61.2	81.8
Misc. Electrical Equipment	85.1	112.7
Motor Vehicle Parts & Accessories	78.5	100.0
Aircraft	104.0	122.2
Aircraft & Missile Engines	33.3	56.2
Misc. Aircraft & Missile Engines	61.2	85.1
Engineering & Scientific Instuments	75.4	96.0
Mechanical Measuring Devices	38.8	69.4
Surgical & Medical Instruments	36.9	38.8
Surgical Appliances & Supplies	40.8	42.8
Optical Instruments & Lens	26.5	47.0
Ophthalmic Goods	38.8	85.1
Photographic Equipment & Supplies	19.0	31.5
Hard Surface Floor Coverings	42.8	42.8

APPENDIX M
COMPUTED SURGE RATIO FOR EACH INDUSTRY
BASED ON PREFERRED & PRACTICAL CAPACITY RATES

INDUSTRY	PREFERRED SURGE RATIO	PRACTICAL SURGE RATIO
Complete Guided Missiles	2.374	1.495
Small Arms	0.001	0.000
Broadwoven Fabric Mills	0.012	0.011
Apparel From Purchased Material	0.000	0.000
Paper Coating & Glazing	0.016	0.012
Commercial Printing	0.004	0.003
Inorganic & Organic Chemicals	0.009	0.008
Chemical Preperations	0.008	0.005
Plastic Materials & Resins	0.010	0.006
Synthetic Rubber	0.005	0.004
Soap & Other Detergents	0.001	0.000
Paints & Allied Products	0.004	0.003
Petroleum Refining Products	0.005	0.003
Misc. Petroleum Refining Products	0.008	0.006
Asphalt Felt & Coatings	0.002	0.002
Tires & Inner Tubes	0.004	0.004
Fabricated Rubber Products	0.077	0.062
Misc. Plastic Products	0.012	0.010
Rubber & Plastic Hose & Belting	0.006	0.004
Leather Gloves & Mittens	0.000	0.000
Luggage	0.000	0.000
Personal Leather Goods	0.002	0.001
Misc. Leather Goods	0.003	0.001
Glass & Glass Products	0.011	0.010
Porcelain Electric Supplies	0.031	0.020
Abrasive Products	0.024	0.013
Asbestos Products	0.010	0.007
Gaskets, Packing & Sealing Devices	0.010	0.004
Minerals, Ground or Treated	0.006	0.006
Misc. Nonmetallic Mineral Products	0.018	0.015
Blast Furnaces & Stell MMills	0.008	0.008
Steel Wire & Related Products	0.005	0.004
Cold Finishing of Steel Shapes	0.006	0.005
Steel Pipes & Tubes	0.003	0.003
Iron & Steel Foundaries	0.018	0.015
Iron & Steel Forgings	0.017	0.015
Metal & Heat Treating	0.410	0.410
Misc. Primary Metal Products	0.039	0.034
Primary Copper	0.058	0.058

Primary Lead	0.081	0.068
Primary Aluminum	0.050	0.042
Misc. Primary Nonferrous Metals	0.031	0.031
Secondary Nonferrous Metals	0.023	0.015
Copper Rolling & Drawing	0.022	0.019
Aluminum Rolling & Drawing	0.034	0.033
Misc. Nonferrous Rolling & Drawing	0.061	0.048
Nonferrous Wire Drawing & Insulating	0.026	0.022
Aluminum Casting	0.019	0.017
Brass, Bronze, & Copper Casting	0.025	0.014
Misc. Nonferrous Casting	0.058	0.032
Nonferrous Forgings	0.050	0.050
Fabricated Structural Metal	0.004	0.002
Fabricated Plate Work	0.003	0.002
Sheet Metal Work	0.007	0.006
Prefabricated Metal Buildings	0.016	0.009
Screw Machine Products	0.043	0.030
Automotive Stampings	0.002	0.001
Misc. Metal Stampings	0.019	0.015
Cutlery	0.003	0.002
Misc. Hand & Edge Tools	0.009	0.007
Hand Saw & Saw Blades	0.008	0.002
Misc. Hardware	0.011	0.006
Plating & Polishing	0.053	0.046
Metal Coating & Allied Services	0.007	0.007
Misc. Fabricalted Wire Products	0.035	0.023
Pipe, Valves, & Pipe Fittings	0.007	0.004
Metal Foil & Leaf	0.007	0.007
Misc. Fabricated Metal Products	0.013	0.011
Misc. Internal Combustion Engines	0.001	0.001
Lawn & Garden Equipment	0.000	0.000
Oil Field Machinery	0.000	0.000
Machine Tools, Metal Cutting Types	0.003	0.002
Machine Tools Metal Forming Types	0.003	0.002
Special Dies & Tools	0.035	0.028
Power Driven Hand Tools	0.001	0.001
Rolling Mill Machinery	0.001	0.001
Misc. Metalworking Machinery	0.006	0.004
Pumps & Compressors	0.011	0.008
Ball & Roller Bearings	0.011	0.010
Power Transmsission Equipment	0.006	0.004
Misc. General Industry Machinery	0.006	0.004
Misc. Machinery (Except Electrical)	0.038	0.018
Electrical Computing Equipment	0.006	0.004
Typewritters & Office Machines	0.020	0.017
Refrigeration & Heating Equipment	0.001	0.000
Instruments to Measure Electricity	0.038	0.020
Transformers	0.005	0.004

Switchgear & Switchboard Apperatus	0.004	0.003
Motors & Generators	0.012	0.008
Industrial Controls	0.014	0.011
Carbon & Graphite Products	0.040	0.034
Misc. Electrical Industrial Apperatu	0.018	0.010
Electric Lamps	0.002	0.001
Lighting Fixtures & Equipment	0.022	0.020
Wiring Devices	0.013	0.011
Radio & TV Receiving Sets	0.063	0.049
Radio & Communication Equipment	1.514	0.918
Electron Tubes	0.192	0.137
Semiconductors & Related Devices	0.102	0.078
Misc. Electronic Components	0.139	0.095
Storage Batteries	0.003	0.002
Engine Electrical Equipment	0.016	0.012
Misc. Electrical Equipment	0.008	0.006
Motor Vehicle Parts & Accessories	0.029	0.023
Aircraft	0.034	0.029
Aircraft & Missile Engines	3.465	2.053
Misc. Aircraft & Missile Engines	1.553	1.117
Engineering & Scientific Instuments	0.010	0.008
Mechanical Measuring Devices	0.013	0.007
Surgical & Medical Instruments	0.001	0.001
Surgical Appliances & Supplies	0.005	0.004
Optical Instruments & Lens	0.044	0.025
Ophthalmic Goods	0.003	0.001
Photographic Equipment & Supplies	0.022	0.013
Hard Surface Floor Coverings	0.000	0.000

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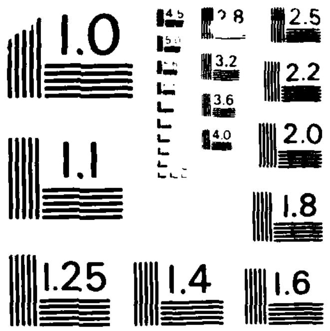

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VITA

Captain William K. Murphy was born on 15 May 1957 in Massapeaqua, New York. He graduated from Smithtown High Scholl East in Smithtown, New York, in 1975, and attended the U.S. Air Force Academy. He received a degree of Bachelor of Science in Economics in May 1979, and was commissioned a second lieutenant in the USAF. Upon graduation he was assigned to Electronic Systems Division at Hanscom AFB, Massachusetts, and served as a program analyst on various Air Force programs until 1982. In 1982, Captain Murphy was assigned to the U.S. Air Force Academy were he served as a member of the Athletic Department faculty before he entered the School of Engineering, Air Force Institute of Technology, in May 1985.

Permanent address: 32 Colgate Dr.
Smithtown, New York 11787

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TITLE: An Analysis of the Space Sector's Surge Capacity: An Input-Output Approach

THESIS ADVISOR: Joeseph P. Cain, PH.D.

This study examines the Space sector's surge capacity in the context of the classical input-output paradigm. It takes as its basis for evaluating the surge potential the concept of available industrial capacity, using the methodology propossed by Michael D. Miller in his report,"Measuring Industrial Adequacy for a Surge in Military Demand."

The investigation begins with a brief history of this country's mobilization and surge policies, and analyzes the need for industrial planning in the Space sector. This study then focus on the functions of space operations and its necessary products. Next, it develops a working definition of the Space sector.

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BLOCK 19 (continued)

A discussion of input-output analysis, its theory, applications, and limitations is included to set the stage for determining the Space sector's interindustry dependencies--at all levels of the economy.

The study concludes by calucalting the amount of production required for each industry to support a surge in space products, and also in determining the vulnerability each industry faces in supporting that surge.

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